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ACOUSTICS

UDC 621.315.592

SURFACE ACOUSTIC SHEAR WAVES IN SEMICONDUCTORS

Leningrad FIZIKA I TEKHNIKA POLUPROVODNIKOV in Russian Vol 14, No 5, May 80
pp 882-885 manuscript received 31 Aug 79

POLZIKOVA, N. I. and GULYAYEV, Yu. V., Institute of Radio Engineering and Electronics, USSR Academy of Sciences

[Abstract] Generation of a surface acoustic wave requires zero normal stresses on the free surface. It has been demonstrated that surface acoustic waves of purely shear type with mechanical displacement parallel to the surface can be set up in piezoelectric crystals of a certain class. In this case the condition of zero normal stress is satisfied through mutual compensation of the normal stresses due to mechanical displacement and due to the piezoelectric effect. Theory also suggests that surface acoustic waves of purely shear type may be set up in conductive piezoelectric crystals. In this case, the normal stress due to mechanical displacement would be compensated by the stress that arises due to the action of electrons on the crystal lattice through the deformation potential. In this paper it is shown that conditions for nearly shear surface acoustic waves can be met in semiconductor crystals of CdS type in the C_{6v} symmetry group with XZ-cut surface. These waves show oscillatory damping with increasing depth. The authors thank P. Ye. Sil'berman and V. P. Pleskiy for discussing the work and for constructive remarks. References 6: 4 Russian, 2 Western.
[81-6610]

FORWARD AND REVERSE CONVERSION OF SURFACE ACOUSTIC WAVES BY A PERIODIC MAGNETIC STRUCTURE

Leningrad ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 50, No 10, Oct 80
pp 2236-2238 manuscript received 30 Jul 79, after revision 27 Dec 79

POL'SKIY, A. I., VERSHININ, V. V. and YAKOVCHUK, V. Yu., Institute of Physics imeni L. V. Kirenskiy, Siberian Department, USSR Academy of Sciences, Krasnoyarsk

[Abstract] An examination is made of the feasibility of using artificially created periodicity of magnetic properties along the assumed direction of propagation of a surface acoustic wave on a magnetostriction film for forward and reverse conversion of electromagnetic energy to the energy of surface acoustic waves. The film was sputtered on a glass acoustic line, and interdigital transmitting and receiving structures were formed on the ends of the line by photolithography. The transducers were placed in coils for setting up a homogeneous field and recording the field induced by the interdigital structure due to elastic strain. Measurements of the double conversion signal as a function of the constant magnetizing field applied perpendicular to the direction of propagation of the surface acoustic wave showed that a periodic magnetic structure can be used for this type of double conversion. Maximum conversion efficiency is observed in fields close to the field of anisotropy of the transducer film. The output signal is a nonlinear function of the magnetizing field. Figures 2, references 4: 3 Russian, 1 Western.
[79-6610]

UDC 666.655

A STUDY OF NEW PIEZOELECTRIC MATERIALS FOR SURFACE ACOUSTIC WAVE DEVICES

Vilnius NAUCHNYYE TRUDY VYSSHIKH UCHEBNYKH ZAVEDENIY LITOVSKIY SSR: UL'TRAZVUK in Russian No 12, 1980 pp 97-102 manuscript received 30 Apr 79

BONDARENKO, V. S., GAYVYANIS, R. Yu. and KRUTOV, A. P., Vilnius Structural Engineering Institute

[Abstract] Experimental and theoretical values for the temperature delay coefficient, SAW velocity, electromechanical coupling factor and the ratio of the change in velocity due to metallization to the SAW velocity are summarized in tabular form for both monocrystalline and polycrystalline SAW devices. Experimental delay lines were made from $LiTaO_3$ with dimensions of 20 x 10 x 2 mm, consisting of two opposing-stub converters having two pairs of electrodes each with a period of 124 micrometers. The spacing between the converters was about 15 mm; the computed SAW velocity based on the delay time was 3.33 km/sec for a ZY cut and 3.23 km/sec for a YZ cut. The most effective cuts for $Bi_{12}GeO_{20}$ are (001) and (111) cuts with SAW propagation along the (110) axis. Experimental delay lines of this material with dimensions of 60 x 25 x 3 mm were tested to determine the temperature delay coefficient and SAW velocity; these values were in good agreement with theory, though the electromechanical coupling factors are 20% higher than given in previous literature. Since these monocrystalline

materials suffer the drawback of high cost and small size, attention is turned to such polycrystalline structures as piezoceramic zirconate-lead titanate (ZLT) and sodium-lithium-niobate (SLN) systems. Values of the mechanical Q, coupling factor and dielectric permittivity are given in a table for a variety of these ceramics. The highest Q's are found among the ZLT systems (up to 3,500 with a permittivity of 280); the highest Q for the SLN systems is around 1,250 (with a permittivity of 115). The parameters of experimental delay lines using these materials are summarized, showing the basic geometric dimensions, the brand of ceramic used, the center frequency (from 8.3 to 26 MHz), the insertion attenuation (22.5 to 86 dB) as well as the temperature delay coefficient (from $3.6 \cdot 10^{-5}$ 1/deg to $13.0 \cdot 10^{-5}$ 1/deg). The SAW attenuation is plotted as a function of frequency based on these data in a range of 10 to 30 MHz for compounds with different grain sizes and good agreement with theory is noted. Figures 2.
[96-8225]

UDC 621.373-187.4:534

A STUDY OF THE POSSIBILITIES OF VARYING THE AMPLITUDE-FREQUENCY RESPONSE OF SURFACE ACOUSTIC WAVE DEVICES BY MEANS OF ION IMPLANTATION

Vilnius NAUCHNYYE TRUDY VYSSHIKH UCHEBNYKH ZAVEDENIY LITOVSKOY SSR: UL'TRAZVUK in Russian No 12, 1980 pp 103-106 manuscript received 7 May 79

VALATKA, R. and IONELYUNAS, S., Kaunas Polytechnical Institute imeni A. Snechkus

[Abstract] Since the center frequency of the amplitude-frequency response of a SAW bandpass filter is uniquely related to the wave propagation over the surface of the device, it is possible by changing the mechanical properties of the substrate to change the SAW propagation velocity; with constant geometry of a structure, this can shift the center frequency. This paper is an experimental study of the use of ion implantation to change the mechanical properties of an $LiNbO_3$ YZ-cut crystal and thereby shift the center frequency of the amplitude-frequency response of an SAW filter. The ion implantation energy was 150 KeV; H^+ and Ne^+ ions were implanted at doses of $10^{12} - 10^{16}$ cm^{-2}. The test circuitry used to measure the relative frequency deviation in the implanted device employs two identical channels to cancel the frequency drift due to heating with exposure to the high energy ions. The range of variation in the response was studied for an SAW filter with a center frequency of 70 MHz. The relative deviation in the center frequency as a result of the irradiation of the entire acoustic conductor from the dose of H^+ and Ne^+ ions is plotted graphically, revealing the nature of the deviation as a function of the type of ions at doses as low as $10^{12} - 10^{13}$ cm^{-2}. No change in the shape of the filter amplitude-frequency response was detected following ion implantation. The relative change in the SAW velocity and the center frequency deviation related to it depends on the ratio of the depth of ion implantation to the acoustic wavelength. Changing the frequency response and tuning the center frequency of bandpass SAW filters by means of ion implantation are possible, and are of practical interest because of the ease and precision of execution. Figures 3; references: 2 Russian.
[96-8225]

UDC 621.315.592

INTERACTION OF ELASTIC SURFACE WAVES WITH INJECTED CARRIERS IN PIEZOCRYSTALS

Leningrad FIZIKA I TEKHNIKA POLUPROVODNIKOV in Russian Vol 14, No 9, Sep 80
pp 1823-1826 manuscript received 25 Feb 80

ADOL'F, Ye. M., TIMAN, B. L. and FAYNER, M. Sh., Institute of Radio Engineering and Electronics, USSR Academy of Sciences, Moscow

[Abstract] Interaction between injected carriers and acoustic waves has been theoretically predicted in piezoelectric crystals. The effect has been experimentally observed on the body waves in a plate of cadmium sulfide, and it has been demonstrated that it could be used as a basis for acoustoelectric generators. In this paper the authors consider the feasibility of using carrier injection to influence the propagation of surface acoustic waves in high-resistance material. Experiments were done on a cadmium sulfide crystal oriented for generation and propagation of piezoelectric Rayleigh waves. A high-resistance layer was produced by diffusion of an acceptor dopant on one surface to which interdigital transmission and reception transducers were applied, tuned to a frequency of 26 MHz. A metallic electrode was applied to this side, and the low-resistance part of the crystal acted as the other electrode. Analysis of the current-voltage characteristics of the high-resistivity layer with application of pulsed voltage to the electrodes shows that surface waves interact with injected carriers. Carrier drift was normal to the direction of surface acoustic wave propagation. It has been theoretically shown that this type of carrier motion can amplify sound. Therefore in principle the injection of free carriers can yield both absorption and enhancement of a piezo-active surface Rayleigh wave. Figures 2, references 6 Russian.
[78-6610]

UDC 534.26

VERTICAL REFRACTION OF NORMAL WAVES AND QUASIMODES IN HYDROACOUSTICS OF AN OCEAN SHELF

Moscow VESTNIK MOSKOVSKOGO UNIVERSITETA, SERIYA 3: FIZIKA, ASTRONOMIYA
in Russian Vol 22, No 1, Jan-Feb 81 pp 50-57 manuscript received 29 Jan 79

KUZNETSOV, V. K.

[Abstract] In previous papers the author described horizontal refraction of normal waves in a wedge-shaped region as applied to the hydroacoustic problem of propagation of sound in a wedge-shaped shelf. In a shelf of arbitrary profile for a sufficiently smooth change in ocean depth there is an analogous pattern of refraction of quasimodes. In either case, horizontal refraction is the main factor that determines the nature of the acoustic field. In this paper, vertical refraction of normal waves is considered on the most typical example in hydroacoustics, where the index of refraction of the bottom $n = c/c_1 < 1$ and the shelf

is wedge-shaped. An analysis is made of waveguide propagation of underwater sound under conditions where the ocean depth changes with distance. When horizontal refraction carries the normal waves and quasimodes out of the waveguide region, vertical refraction produces radiation of acoustic waves into the underlying half-space. This effect is examined. Figures 2, references 6: 5 Russian, 1 Western.
[100-6610]

CRYSTALS AND SEMICONDUCTORS

UDC 621.315.592

DEFECTS IN SILICON WITH EXPOSURE TO HIGH-CURRENT ELECTRON PULSES

Leningrad FIZIKA I TEKHNIKA POLUPROVODNIKOV in Russian Vol 14, No 5, May 80
pp 995-997 manuscript received 29 Oct 79

DVURECHENSKIY, A. V., KASHNIKOV, B. P. and SMIRNOV, L. S., Institute of Semiconductor Physics, Siberian Department, USSR Academy of Sciences, Novosibirsk

[Abstract] The rate of injection of defects in semiconductors depends on the intensity of irradiation. One of the reasons for this dependence is the redistribution of Frenkel pairs among several simultaneously existing channels. This redistribution can be attributed to a change in the charge state of the reacting components as the particle flux density is varied. If the intensity of irradiation is constant while the integrated flux is strongly increased, new channels of complex formation should be expected. These channels are due to accumulation of injected complexes to high concentrations, resulting in interaction with the Frenkel pairs produced by irradiation. The authors study the rate of injection of A-centers (the V-O complex) in silicon at high electron current densities (up to tens of A/cm^2), and compare the results with data on injection rates at lower current densities. In addition, since the use of high-current beams enables advancement into the region of higher doses, the accumulation of E-centers (the V-P complex) was compared in oxygen-containing and oxygen-free silicon at heavy doses of electron irradiation (up to 10^{20} cm^{-2}). Analysis of the experimental results for different exposure conditions with 1 MeV electrons showed that for pulse durations of 3-60 μs the rate of introduction of A-centers is practically independent of electron current in the beam from about 10 mA/cm^2 up to 4 A/cm^2, being equal to the maximum injection rate observed with exposure to a continuous beam. In the nanosecond pulse range, the A-center injection rate initially more doubles (at 4 A/cm^2) and then falls off as the current density increases. Studies of E-center accumulation revealed a new channel of complex formation in oxygen-free silicon: V + E-center = V_2P, i. e. a complex containing two vacancies and phosphorus. Figures 3, references 6: 5 Russian, 1 Western.
[81-6610]

UDC 539.216.2:535

INFLUENCE OF ION IMPLANTATION ON THE STRUCTURE OF SILICON DIOXIDE FILMS PRODUCED BY DIFFERENT METHODS

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 34, No 2, Feb 81
pp 329-334 manuscript received 15 Feb 80

SELEZNEV, B. I., MOSKALEV, G. Ya. and TKAL', V. A.

[Abstract] An investigation is made of the effect of implantation of ions of BF_2^+, B^+, P^+ and Ar^+ on the structure of silicon dioxide films produced by thermal oxidation in moist oxygen, by pyrolysis of tetraethoxysilane, by oxidizing a silane with oxygen and by reactive cathode sputtering. Germanium and silicon substrates were used. The implantation was done in dopant doses of 10^{12}-10^{16} cm^{-2} with energies of 50 keV for BF_2^+ and B^+, 100 keV for P^+ and 75 keV for Ar^+. Film thicknesses were sufficient to prevent the implantation from reaching the oxide-substrate interface. It was found that radiation structural changes are less effective in films made by oxidation with oxygen and by pyrolysis of tetraethoxysilane than in those produced by thermal oxidation of silicon and by sputtering. Implantation of BF_2^+ and P^+ ions leads to formation of boron and phosphorus oxides starting with doses of 10^{16} cm^{-2}. Formation of boron oxide is observed immediately after implantation, while phosphorus oxide shows up after annealing in nitrogen or argon at temperatures above 800°C. Figures 4, references 6: 5 Russian, 1 Western.
[99-6610]

UDC 621.315.592

ELECTRIC AND RECOMBINATION PROPERTIES OF ELECTRON-BOMBARDED p-SILICON

Leningrad FIZIKA I TEKHNIKA POLUPROVODNIKOV in Russian Vol 14, No 9 Sep 80
pp 1756-1759 manuscript received 13 Jul 79, after revision 6 Feb 80

KOLODIN, L. G. and MUKASHEV, B. N., Institute of High-Energy Physics, KaSSR Academy of Sciences, Alma-Ata

[Abstract] The nature of annealing of radiation defects in silicon produced by non-crucible zone melting depends on the dopant. This is due to the secondary defects formed during irradiation and annealing as a result of interaction of simple defects with impurities and with each other. The authors investigate processes of defect formation under the action of fast electrons in silicon doped with boron or aluminum. The specimens were irradiated with 1.8 MeV electrons. It is shown that the defect coefficient determined from the change in diffusion length of minority carriers is independent of dopant type at a bombardment temperature of 120 K. In the case of exposure at 300 K the defect coefficient for crystals doped with silicon is about 1/4 that of boron-doped silicon. The defect coefficient for all crystals at 300 K depends on the resistivity as $K \sim \rho^{-0.66}$. Correlation analysis of the annealing parameters and the positions

of energy levels of defects shows that the difference in radiation resistance of recombination parameters of crystals doped with silicon or boron is apparently due to the different nature of the centers responsible for recombination in these materials. In conclusion the authors thank V. S. Vavilov for interest. Figures 2, references 24: 7 Russian, 17 Western.
[78-6610]

UDC 621.315.592

THERMOSTIMULATED LUMINESCENCE FLASH IN GaP

Leningrad FIZIKA I TEKHNIKA POLUPROVODNIKOV in Russian Vol 14, No 9, Sep 80 pp 1699-1703 manuscript received 11 Jan 80

NECHAYEV, V. M., POLTORATSKIY, E. A. and SURIS, R. A.

[Abstract] The effect of thermostimulated luminescence is usually observed in wide-band semiconductors when they contain sticking levels for nonequilibrium carriers. When a pre-excited crystal is heated, nonequilibrium carriers are thermally ejected from the sticking level into the band, and if they are then captured onto radiative recombination centers, luminescence arises. In this paper it is shown that a luminescence flash may be observed upon heating not only in this case, but also when the parameters of the radiative recombination centers themselves depend on temperature. Inter-impurity radiative recombination is considered in an n-type semiconductor under condition that the probability of inter-impurity transition increases with rising temperature. It is assumed that the fraction of nonequilibrium carriers that recombine through this channel is small, and that most of the carriers recombine through other radiative and non-radiative channels, which thus determine the concentration of nonequilibrium carriers in the band. It is shown that in the case of rapid heating, when the filling function of the acceptor centers cannot keep up with the temperature rise, luminescence intensity begins to depend on the probability of radiative transition, which leads to the flash of emission. This effect is experimentally studied in n-GaP single crystals in the 1.5 eV radiation band. Figures 2, references 3: 2 Russian, 1 Western.
[78-6610]

MAGNETIC BUBBLES IN PSEUDO-UNIAXIAL CRYSTALS

Leningrad FIZIKA TVERDOGO TELA in Russian Vol 22, No 8, Aug 80 pp 2523-2525 manuscript received 31 Mar 80

SABITOV, R. M., VAKHITOV, R. M. and FARZTDINOV, M. M., Bashkir State University imeni 40th Anniversary of the October Revolution, Ufa

[Abstract] A characteristic feature of garnet-ferrite films is the simultaneous presence of an induced easy magnetization axis and crystallographic cubic

anisotropy (pseudo-uniaxial crystals). An isolated magnetic bubble with a Bloch wall is the model used to analyze the distortions of the bubble due to the cubic symmetry in such materials. It is assumed that the easy magnetization axis coincides with the edges of the cube and two cases are treated: 1. The magnetization axis lines up with the OZ axis directed along the [001] axis; 2. The magnetization axis is directed along the [111] axis. The analytical expressions derived for the bubble geometry in these two cases indicate that in the first case it is possible for the bubble to have a four-lobed configuration with a boundary of nonuniform width. In the second case, the bubble can exhibit three lobes, or six, depending on the value of a constant parameter in the expressions found for the internal radius of the bubble and the boundary. The factors affecting the bubble shape are qualitatively and quantitatively discussed in brief. All distortions are minor close to the collapse field and become significant close to the field of elliptical instability and do not occur in the absence of cubic anisotropy. The inhomogeneities in the shape of the bubble and its boundary should also have an impact on the dynamic properties of the bubble. Figures 2; references 4: 1 Russian, 3 Western.
[97-8225]

ELECTRICITY AND MAGNETISM

UDC 532.593

THE ELECTRICAL CONDUCTIVITY OF AIR BEHIND A SHOCK WAVE FRONT WITH DETONATION OF CONDENSED EXPLOSIVES

Novosibirsk FIZIKA GORENIYA I VZRYVA in Russian Vol 16, No 2, Mar-Apr 80
pp 109-116 manuscript received 14 May 79

PUNKEVICH, B. S. and STEPANOV, B. M., Moscow

[Abstract] The electrical conductivity of the gas behind a shock front is measured for detonation of spherical charges of condensed explosives in air of different initial densities by means of a noncontact induction method. The method gives independent results, and in addition is free of the disadvantages of probe methods resulting from direct contact of the probe with plasma. The straightforward interpretation of results makes the proposed method applicable to studies of high-collisional plasma formations of explosive type. The experiments were done in an explosive barochamber made in the form of a cylinder 350 mm in diameter and 500 mm long. Air pressure was varied from 0.01 to 1 atm. An inductive pickup carrying the explosive was placed in the chamber and connected to the measuring equipment by a coaxial cable. Measurement of electrical conductivity of the air behind the shock front was based on dissipation of magnetic field energy of the pickup in the conductive gas. Measurement was by a balanced r-f bridge. The results show that conductivity arises due to thermal ionization of the air close to the contact surface of the products of explosion. The electrical conductivity on the contact surface decreases with a reduction in the initial density of the air. There is a concomitant increase in the effective thickness of the conductive layer. Figures 6, references 17: 11 Russian, 6 Western.
[74-6610]

UDC 621.378.323

STIMULATED EMISSION OF A HIGH-CURRENT ELECTRON BEAM IN A PERIODIC MAGNETIC FIELD

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 256, No 5, 1981 pp 1106-1108
manuscript received 23 Sep 80

DIDENKO, A. N., ZHERLITSYN, A. G., KOZHEVNIKOV, A. V., MEL'NIKOV, G. V., FOMENKO, G. P. and SHTEYN, Yu. G., Scientific Research Institute of Nuclear Physics affiliated with Tomsk Polytechnical Institute imeni S. M. Kirov

[Abstract] A great deal of experimental and theoretical research is currently being done on free-electron lasers because of their anticipated advantages of wide-band continuous tuning, as well as high output power and high efficiency. Pumping of such lasers by high-current electron beams results in a three-wave parametric process in which amplification of the backscattered wave is due to interaction between the pumping wave and either the space-charge wave of the beam or the cyclotron wave. It is shown that the driving magnetic field affects emission frequency only for interaction with the cyclotron mode. In this paper the authors give the results of investigation of stimulated emission in the millimeter band by a high-current electron beam propagating in the magnetic field of a helical undulator. The output was picked up by a cryogenic germanium detector, and the emission frequency was measured by waveguide filters. The curves for microwave power of the emission as a function of the driving magnetic field and the undulator field show a relative maximum, which is attributed to the fact that the saturation length becomes greater than the length of the undulator in strong magnetic fields. While the emission wavelength was found to be independent of the driving magnetic field, it was also found that an increase in electron density increases the wavelength of the stimulated emission. This means that interaction takes place on the space-charge mode. Emission with power of 2 MW and wavelength of 13 mm was produced in an undulator with a period of 4 cm, and a power of 2.5 MW on a 7.5 mm wavelength was attained in an undulator with period of 2.8 cm using a solid beam. A tubular beam gave emission of 20 MW on a wavelength of 11 mm in the second undulator. Pulse duration was 50 ns. While efficiency was low, it could be improved by optimizing the parameters of the facility.
Figures 3, references 12: 5 Russian, 7 Western.
[91-6610]

UDC 532.5.013.12

THE SIZE OF POLYMER PARTICLES AND REDUCED HYDRODYNAMIC DRAG

Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 39, No 5, Nov 80 pp 815-819 manuscript received 23 Nov 79

USKOV, I. A., USKOVA, Ye. T. and BELOVA, N. M., Kiev State University imeni T. G. Shevchenko

[Abstract] An investigation is made of the way that particle size affects the capacity of polymer additives for reducing the turbulent drag of liquids with consideration of particle concentration in the deformable volume of liquid. The analysis is based on the example of biopolymers of surface secretions of aquatic animals. The hydrodynamic activity of such secretions is studied as a function of particle diameter. It is shown that the hydrodynamic activity of biopolymers as a function of particle size is described by a curve with a smooth maximum in the vicinity of 200-400 nm. The minimum particle size is found for which biopolymers show a capacity for reducing drag. The experimental curve is described by the equation

$$Ed^3 = 3.00 \cdot 10^8 (d - d_0)^{2.26},$$

where E is hydrodynamic activity, d is average particle diameter and d_0 is minimum particle diameter. The calculated optimum particle size agrees with experimental data, thus confirming the proposed equation. Figures 2, references 9: 7 Russian, 2 Western.
[93-6610]

UDC 517.958:533.6.011

SUBSONIC GAS FLOW AROUND A WING PROFILE

Moscow ZHURNAL VYCHISLITEL'NOY MATEMATIKI I MATEMATICHEKOY FIZIKI in Russian Vol 21, No 1, Jan-Feb 81 pp 139-149 manuscript received 22 May 80

MELLER, N. A., Moscow

[Abstract] The problem of subcritical flow around a wing profile is solved by A. A. Dorodnitsyn's method of integration with respect to a small parameter

proposed in a paper to the Conference on Current Problems in Mathematical Physics and Computational Mathematics at Moscow State University in February 1978. In this technique, the Poisson equation for a circle is solved with respect to a small parameter (dimensionless velocity of the unperturbed flow) on each step. As a preliminary stage, the profile is conformally mapped onto a circle. The solution is found each time by multiplying a fixed matrix by a vector. This immediately yields the velocity fields at different Mach numbers of the oncoming flow. The proposed method enables satisfaction of the Zhukovskiy condition at a non-zero angle of attack on each step. The author thanks A. A. Dorodnitsyn for useful advice in solving the problem. Figures 6, reference 1 Russian.
[71-6610]

UDC 517.958:533.7

CALCULATION OF SUPERSONIC FLOW OF A VISCOUS GAS AROUND SOLIDS OF REVOLUTION AT SMALL ANGLES OF ATTACK

Moscow ZHURNAL VYCHISLITEL'NOY MATEMATIKI I MATEMATICHESKOY FIZIKI in Russian Vol 21, No 1, Jan-Feb 81 pp 150-156 manuscript received 7 Feb 78, after revision 7 Jan 80

KARYAKIN, V. Ye., Leningrad

[Abstract] A numerical method is proposed for solving the problem of three-dimensional flow of a viscous thermally conductive gas around a blunt solid of revolution at supersonic velocity. The flow pattern in the shock layer in front of the body is calculated at small angles of attack by the small parameter method. The initial equations are Navier-Stokes equations simplified for large Reynolds numbers, and the Hugoniot conditions are assumed on the shock wave. The solution functions are expanded in powers of the angle of attack. Solutions are given for an ellipsoid and for spherically blunted cones with various vertex angles. Figures 2, references 4: 3 Russian, 1 Western.
[71-6610]

UDC 681.787.7:004.14:532.593

USE OF A DIFFRACTION SHEAR INTERFEROMETER IN SHOCK TUBE STUDIES

Leningrad ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 50, No 10, Oct 80 pp 2201-2204 manuscript received 16 Apr 79, after revision 16 Nov 79

KOLYSHKINA, L. L., SHEVTSOV, V. D. and ARKHIPOV, V. V., Leningrad State University imeni A. A. Zhdanov

[Abstract] The authors discuss the peculiarities of the diffraction interferometer based on the IAB-451 standard shadow instrument as one of the most convenient shear interferometers for use in shock tube research. Interference patterns are

given for interaction of a shock wave with a right prism in a Vieille shock tube. The image quality is comparable to that produced by the Mach-Zehnder interferometer. The high image quality means that the device can be used in holographic interferometry. The authors thank N. P. Mende for assistance in the initial stage of the work, and Ye. F. Zhigalko for interest in the work and discussion. Figures 4, references 3 Russian.
[79-6610]

UDC 532.526

LONGITUDINAL FLOW OF A VISCOELASTIC FLUID OVER A SEMI-INFINITE PLATE WITH CONSIDERATION OF HEAT EXCHANGE

Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 40, No 2, Feb 81 pp 225-230
manusciipt received 17 Mar 80

SOUNDALGEKAR, V. M. and RAMANA MURTI, T. V., Indian Technological Institute, Bombay, India

[Abstract] A numerical analysis is made of the dynamic and temperature boundary layers on a semi-infinite plate in a longitudinal flow of a viscoelastic fluid of Walters B' type [see K. Walters, "The Solution of Flow Problems in the Case of Materials with Memory. I", JOURNAL DE MECANIQUE, Vol 1, 1962, pp 479-488]. A system of nonlinear ordinary differential equations is derived an numerically solved. Curves are given showing velocity and temperature profiles, and tables are given summarizing the values of friction stress and thermal fluxes in the boundary layer. It is found that an increase in shear modulus reduces friction and heat exchange, while an increase in the Prandtl number is accompanied by an increase in heat exchange. Figures 2, references 12 Western.
[94-6610]

UDC 532.58

EMISSION OF INTERNAL WAVES AS BODIES MOVE VERTICALLY THROUGH AN INHOMOGENEOUS FLUID

Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 39, No 4, Oct 80 pp 619-623
manuscript received 10 Aug 79

GORODTSOV, V. A., Institute of Problems of Mechanics, USSR Academy of Sciences, Moscow

[Abstract] When bodies move in a fluid of inhomogeneous density in a gravitational field, internal gravity waves are stimulated in addition to acoustic waves, and the loss of wave momentum causes additional wave drag. In the linearized approximation, a simpler problem is considered in which singular sources are assumed to be in some sense equivalent to the moving bodies. Such substitutions

have an exact sense in the theory of an ideal homogeneous fluid. It can be assumed that they are valid for a weakly inhomogeneous fluid. An approach of this kind is used in this paper to calculate the total energy losses on wave formation with vertical movement of bodies at subsonic velocities. The fluid is modeled by a stratified medium of simple type. A formula is derived for the spectral distribution of energy of radiation of internal waves from a source distributed along the axis of motion. Simple formulas are also derived for energy losses by a doublet in the two-dimensional and three-dimensional cases. An analysis is made of the way that energy lost to radiation of internal waves depends on dimensional parameters. References 7: 6 Russian, 1 Western.
[69-6610]

CRITERIA FOR AMPLIFICATION OF AN OBLIQUELY INCIDENT SHOCK WAVE BY A LAYER OF A POROUS SUBSTANCE

Novosibirsk FIZIKA GORENIYA I VZRYVA in Russian Vol 16, No 5, Sep-Oct 80 pp 78-80 manuscript received 18 Feb 80

KOSTYUKOV, N. A., Novosibirsk

[Abstract] Transmission of an obliquely incident shock wave from a medium with Prandtl-Meyer flow characteristics through a porous layer with negligible damping to a continuous and more rigid medium is analyzed, the problem simulating the conditions in molding of porous materials, or in chemical heat treatment of metals, or in powder coating of monolithic substrates. Refraction and some reflection take place at each boundary of the porous layer with the fluid medium above and with the solid medium below respectively. The pressure transfer through this layer is calculated by the method of polar curves, in pressure-angle coordinates, and a criterion is established which determines when the amplitude of a shock wave in the solid medium will be larger with the porous interlayer than without it. This criterion has the form of an inequality, it relates to the condition for supersonic flow, and involves the angle of incidence as well as the relevant properties of the material. Estimates based on calculations and experiments indicate that there is a wide choice of matching fluid and porous media which will produce amplification of shock waves. Figures 2; references 11: 8 Russian, 3 Western.
[107-2415]

LASERS AND MASERS

THE LASER BEAM IN THE WORLD OF ATOMS AND MOLECULES

Moscow NAUKA I ZHIZN' in Russian No 11, Nov 80 pp 24-32

[Article by Hero of Socialist Labor, Academician Aleksandr Mikhaylovich Prokhorov, winner of the Lenin and Nobel prizes, and Professor V. Letokhov, winner of the Lenin Prize]

[Text] Soviet scientists are doing research at the very frontier of the enormous forefront of science. Numerous examples could be cited of how their fundamental results have become an event of worldwide magnitude, how they have discovered new possibilities of understanding the nature of things, initiated new areas of engineering and technology, and of how their discoveries have rapidly taken a leading place in many areas of practical human activity. One such example is the development and progress of quantum electronics. This field came into existence about a quarter of a century ago, when what seemed to be purely academic research in the field of radio spectroscopy at the Lebedev Physics Institute of the USSR Academy of Sciences [FIAN] led to development of the first quantum oscillators and amplifiers and the origin of an entirely new class of physical devices now known as lasers. The originators of quantum electronics, now Heroes of Socialist Labor and winners of the Lenin and Nobel prizes, academicians Nikolay Gennadiyevich Basov and Aleksandr Mikhaylovich Prokhorov, are still doing active research in this area. These eminent Soviet physicists and their scientific following have done a great deal of pioneering work that has gone into the storehouse of worldwide science and technology, specifically in such fields as development of new classes of lasers, laser-driven nuclear fusion, laser communications and data processing, selective action of laser radiation on matter, and much more.

The advances in laser engineering and technology have been due to a great extent to the fact that Soviet industry has been able to transform the laser fairly rapidly from a custom-made laboratory instrument into a mass-produced device accessible not only to experimental scientists, but also to a wide class of practical specialists. Series production of a wide variety of lasers, rapid assimilation of the scientific advances in quantum electronics in industrial devices combined with in-depth physics research have enabled practical utilization of such valuable properties of laser radiation as coherence, directionality and high power. Lasers are now estensively used in the most diverse areas -- from medicine to metrology, from metal cutting to television and telephony. Some years back, when lasers with continuously tunable frequency (wavelength) of output were developed, still another field of research and application of laser emission began its rapid growth, where use is made of resonant interaction of this radiation with atoms and molecules of matter. This article is devoted to some recent advances of Soviet scientists in this area.

THE SPECTRAL LANGUAGE OF ATOMS AND MOLECULES

It might be best to start this story with a reminder of how light is used to find out about the structure of atoms and molecules, their state, and finally, about the presence of certain atoms and molecules in an investigated multicomponent substance. It is well known that an atom or molecule of any kind has a strictly defined structure, that their architecture is determined by the laws of quantum physics. And this architecture is most intimately related to the most important characteristics of electromagnetic radiation of atoms and molecules.

Just as each string of a guitar or piano has its own frequency of vibration, so the different atoms and molecules "vibrate" differently. And they emit electromagnetic waveforms of very high frequency -- most often visible, infrared or ultraviolet rays. For example the light of a mercury vapor lamp in a quartz envelope, which is extensively used in medicine as a source of ultraviolet rays, is radiation of mercury atoms. Sometimes it is sufficient to measure the wavelengths of radiation, or as we say to analyze its spectrum, by the simplest prism spectrograph to tell what atoms or molecules were the source of this radiation.

Actually, atoms and molecules may emit several different frequencies rather than a single one, and it would be more correct to compare them with a whole group of strings rather than with a single string. The process of radiation itself is due to the fact that the emitter makes a transition from one state to another, losing a certain amount of energy, which is what is transformed to the energy of radiation. There may be different "batches" of this energy, but they always depend strictly on from what state to what other state the emitter has gone. In other words, the amount of energy that is lost by the atom shows up as a qualitative difference in the radiation itself: the more energy the atom has given up, the higher will be the frequency of the radiation, or in other words the shorter will be the wavelength of the emitted electromagnetic wave.

The picture is analogous for the reverse process -- absorption of electromagnetic radiation by an atom or molecule. Such absorption causes a transition of the system to a higher energy level, generally increasing the store of energy, e. g. from some amount E_1 to an amount $E_2 = E_1 + \Delta E$. And as the energy levels E_1, E_2, E_3 and so on cannot have just any value since they can be only strictly defined quantities in accordance with the laws of quantum mechanics, so the electromagnetic radiation is absorbed in completely defined, or in other words "allowed" batches -- quanta. If matter is exposed to a set of quant of different energies, only those quanta will be absorbed that raise the atom or molecule exactly from one energy step to another. But if a quantum with higher or lower energy is incident on the atom or molecule, it will not be absorbed, and to put it simply, will pass by.

The energy of the quantum is determined by its frequency, and we can speak of resonant absorption of quanta, as if the atom or molecule itself picked out from different radiation frequencies only those capable of raising it exactly to a higher energy level. But if transitions to different levels are possible in an atom, then quanta of several different frequencies will be absorbed, and in this case we speak of an absorption spectrum. One atom has one set of such levels E_1', E_2', E_3' and so on, while another has a completely different set E_1'', E_2'', E_3'' and so on, and in this way every atom is typified by its own particular spectrum of absorbed and radiated frequencies. Of course the emission and absorption spectra coincide (see the top sketch on the color insert).

Figuratively speaking, the emission or absorption spectrum is the language in which atoms and molecules tell us about their presence in a complex mixture of substances and about their state. Our knowledge of the chemical makeup of stars in the universe comes exclusively from analysis of their emission spectra. The spectroscopist determines the chemical composition of laboratory specimens in exactly the same way. Of course, unlike the stars, the material specimens ordinarly do not emit on their own, and it is necessary to stimulate luminescence in some way, like the electric current excites the mercury atoms in the quartz lamp, or like the musician makes the string vibrate on an instrument.

SELECTIVE EXCITATION, AND TUNABLE-FREQUENCY LASERS

Atoms and molecules can be excited by laser emission, and most importantly, such excitation is highly selective -- it acts on a strictly defined type of atoms or molecules. Actually, if the frequency of optical waveforms in the laser beam coincides with the natural frequencies of electrons in an atom, or of atoms in a molecule (this is the accepted terminology for frequencies corresponding to the allowed energy transitions), resonant amplification occurs, like the effect in acoustics of resonance of sound waves on a certain frequency with vibrations of some body. By varying the frequency of laser emission, we can tune to resonance, i. e. we can selectively excite atoms or molecules first of one given kind, and then another. The researcher who controls the frequency (wavelength) of laser radiation is in a figurative sense the conductor of the atomic-molecular orchestra, making the necessary instruments of the microcosm "perform". Another analogy familiar to everyone is tuning of a radio receiver to resonance with the transmitter frequency. Of course the situation is essentially the reverse: instead of adjusting the frequency of the atom or molecule (the receiver) we tune the laser (transmitter) so that its frequency coincides with the given resonant frequency of the atoms and molecules that we need.

This unique property of laser light to selectively excite atoms and molecules opens up fundamentally new approaches both in the investigation of matter and in purposeful action on matter. With proper selection of the parameters of laser light, selective interactions are possible with other atomic-molecular objects: from the simplest hydrogen atom to the most complicated giant DNA molecule that is the material carrier of the genetic code.

Thus for selective excitation of different atoms and molecules we need to tune the frequency of laser emission to exact resonance. The earliest lasers worked on a fixed frequency, and for some time it seemed that this would be a permanent feature. However, the problem of frequency variation was solved in various ways, and now a large family of tunable-frequency lasers has been developed. Such lasers now cover a very wide range: from infrared rays (wavelengths of 20-30 μm) to the vacuum ultraviolet (wavelengths of 0.1-0.2 μm).

The rapid progress in the field of tunable lasers has been due to a great extent to their promising applications both in scientific research and in technology. Mention should be made here above all of spectroscopy, monitoring of environmental pollution, laser separation of isotopes, laser production and analysis of especially pure materials, and selective action on biological molecules. We will be talking about some of these fields of application to which Soviet scientists have made a major contribution.

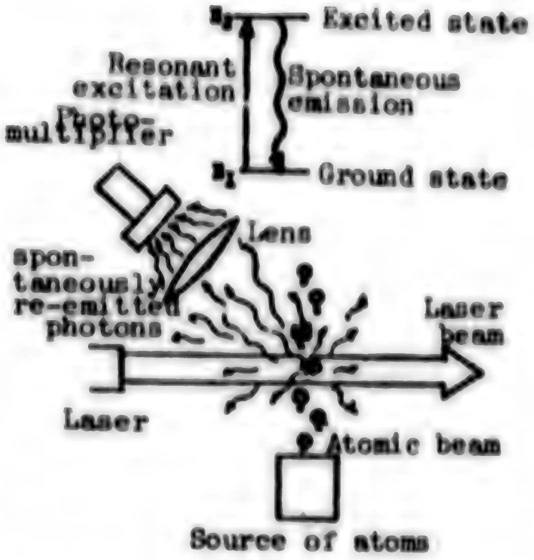
LASER DETECTION OF INDIVIDUAL ATOMS

When the frequency (wavelength) of a laser beam is tuned to resonance with atoms of a selected element, these atoms will be the only ones that receive energy from the light. As they selectively absorb the laser light and repeatedly re-radiate it to all sides, these atoms are literally "lit up", or as we say they fluoresce in the laser beam, and therefore become fully detectable. This principle is the basis of a method of detecting individual atoms. The essence of the technique is explained by Fig. 2. Free atoms that are formed for example upon vaporization of heated metal intersect the laser beam. The frequency of the laser emission is tuned precisely to resonance with the frequency of the quantum transition of an atom of the required kind, let us say to resonance with the energy of transition from the ground state to the first excited state. Even when the laser radiation has a power of a fraction of a watt, the resonating atom makes a transition to the excited state very quickly, within a few nanoseconds, and then returns to the initial state after emitting the absorbed photon in an arbitrary direction.

The process of excitation of the atom by light is called induced excitation, and the release of the photon is called spontaneous emission. The entire cycle of such induced excitation of an atom and spontaneous emission of a photon takes hundredths of a microsecond. At the same time, an atom that has an average thermal velocity of a few hundred meters per second crosses a laser beam of about 1 cm diameter for several tens of microseconds, and may quite possibly repeat the cycle of absorption and re-radiation of photons thousands of times. In other words it may produce a photon flare. The photons scattered by the atom may be collected, sent to a photomultiplier, and the resultant pulse of photoelectrons can be registered by conventional electronic equipment.

Another universal method of detecting atoms is based on the effect of selective photoionization. In this case the excited atom is not returned to the initial state, but rather goes on accumulating energy due to absorption of several photons. Since intensive transition to new and higher energy steps as a rule requires different batches of energy, the atom is simultaneously exposed to pulses from two or even three lasers whose emission frequencies are tuned to resonance with several successive quantum transitions (see bottom sketch on the color insert). As a result of such selective excitation the atom acquires energy sufficient for detachment of an electron, or what is called photoionization of the atom. When this happens, of course, the atom is converted to an ion, which can now easily be registered by conventional electronic facilities.

A peculiarity of the photoionization method of detecting atoms is its exceptionally high selectivity. This is due to the fact that the ion is formed only with exact tuning of all laser frequencies to successive quantum transitions of the atom. These frequencies are strictly specific for each element of the periodic table, and even for different isotopes of the same element. The probability of coincidence or partial overlap of spectral lines of three successive transitions for different atoms is vanishingly small. Therefore such a method is particularly valuable in detection of a very small number of atoms against a background of atoms with similar spectral lines. Another important feature of this method is the capability of easily collecting the detected atoms, since the motion of ions can be readily controlled by an electric field.



At a certain frequency of laser radiation an atom may make a transition to an excited state, absorbing a batch of energy, and then emitting a photon that can be registered by a photomultiplier

There are an enormous number of both applied and fundamental problems in which it is necessary to detect infinitesimal amounts, often called trace amounts of atoms. For example the production of exceptionally pure materials for the needs of semiconductor electronics and other sectors of present-day technology requires exact evaluation of impurities present in the material in minute concentrations. Similar problems arise during analysis of geological specimens in the search for minerals, or when analyzing specimens of water, soil or air for checking the state of the environment.

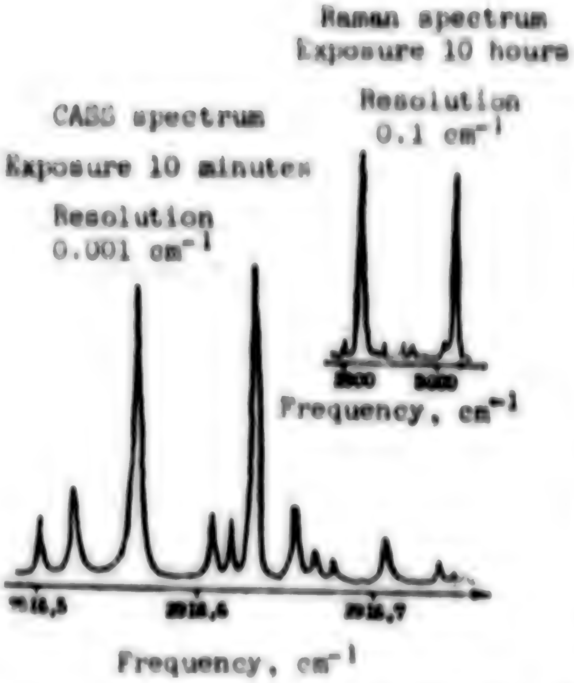
The detection of individual atoms is of particular interest for nuclear physics, where it is necessary to record small numbers of new atoms produced during nuclear reactions in accelerators, or under the effect of cosmic rays or solar neutrinos. Here laser methods are particularly effective since they enable detection not only of rare atoms, but also provide the most valuable information on their isotopic composition, size, and energy of excitation of the nucleus. In this regard, fundamentally new selective laser methods have been developed for registration of short-lived nuclei and their isotopes in the immediate vicinity of the accelerator target, methods of isolating individual atoms formed in dozens of tons of material in a neutrino detector, or methods of finding superdense nuclei in nature. In essence, we are seeing the fruitful synthesis of methods of laser spectroscopy of atoms and nuclear physics, the birth of a new scientific field -- laser-nuclear spectroscopy.

LASER DETECTION OF MOLECULES

When we go from atoms to molecules, the problem gets much more complicated since instead of a hundred elements and a few more hundred isotopes, we are dealing with many thousands of chemical compounds. Here the problem is not only high sensitivity of the laser spectrometer, but also adequate selectivity, i. e. the capacity for distinguishing molecules with very close frequencies of absorption or emission. It is in the handling of this second problem that the laser beam has been exceptionally effective. Let us give two examples to confirm this.

Half a century ago academicians G. S. Landsberg and L. I. Mandelstam and the Indian physicist Raman discovered the effect of combination scattering of light (Raman scattering), which consists in the following. If a substance in solid, liquid or gaseous state is illuminated with monochromatic light, the spectrum of the scattered light reveals several extremely weak satellite radiations in addition to the irradiating spectral line, these satellites being shifted toward lower frequencies into the so-called Stokes region.

These new frequencies (called Raman frequencies) differ from the frequency of the irradiating light by an amount determined by the frequencies of vibrations of the



The laser method of coherent anti-Stokes scattering (CASS) enables investigation of the finest details in the spectra of molecules. At the top is a conventional Raman spectrum of molecules of methane CH_4; at the bottom is a small part of this spectrum produced by the CASS method on a facility in the waveform laboratory of the Lebedev Physics Institute [FIAN]

molecule. Because of this, the Raman method can be an effective means of studying the structure of molecules. However, because of the very low intensity of the scattered light before lasers put in their appearance, the technique did not come into extensive use.

The most important properties of laser radiation -- directionality, monochromaticity, high intensity -- make lasers a practically ideal source for Raman scattering of light, and the method has found application in the laboratories of physicists, chemists and biologists. But thanks to progress in tunable lasers in recent years, new methods have been developed that considerably extend the capabilities of Raman spectroscopy. One of these is the method of coherent anti-Stokes scattering [the CASS method]. The technique is essentially as follows. Molecules are irradiated simultaneously by two tunable lasers. When their frequency difference $\nu_1 - \nu_2 = \Delta\nu$ coincides with the resonant frequency of the molecule ν_{mol}, its vibrations are pumped up, all molecules of the given type in the irradiated volume being pumped up that satisfy the resonance condition $\Delta\nu = \nu_{mol}$. Such a set of synchronously (or as we say coherently) oscillating molecules very effectively scatters laser radiation, and as a result when the substance is exposed to a third laser beam with frequency ν_3, a satellite shows up in the spectrum of the scattered light that is shifted into the short-wave (anti-Stokes) region by the frequency of the vibrations ν_{mol}. Moreover, the scattered anti-Stokes radiation has high directionality since the molecules themselves are pumped up by highly directional laser beams. This enables very efficient collection of all scattered light with a brightness millions of times that of Raman signals produced under the same conditions when molecules are exposed to single-frequency laser emission.

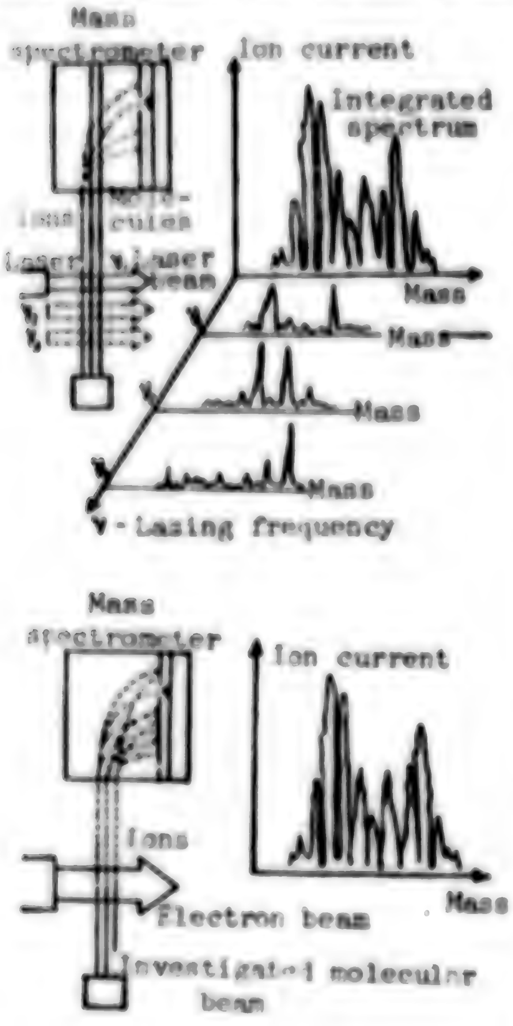
Physicists at Moscow University and FIAN have made a considerable contribution to development of the CASS method, and have demonstrated its great potential capabilities in measurement of the spectrum of vibrations of molecules with a relatively small amount of the study material. As an illustration, Fig. 4 shows a small section of the vibrational spectrum of the methane molecule CH_4 in the region of 3.39 µm produced at FIAN. This section contains extremely fine details that are not present in the Raman spectrum (shown at the top) under ordinary conditions.

It would be pertinent to mention here that specialists working on the development of laser spectroscopy do not denigrate the remarkable advances of other methods of spectroscopic research, and understand that laser spectroscopy supplements rather than displaces these methods, in many cases providing information unattainable by the other methods. For example even now laser spectroscopy, and in particular the

Raman and especially the CARS methods, enable determination of the structure of molecules at a concentration of 10^{14}-10^{15} particles per cubic centimeter. This is a millionth of the threshold concentration needed for other perfected spectrometric methods.

But ahead of us is the pressing task of selective detection of molecules at much lower concentrations, down to 10^{5}-10^{10} molecules per cubic centimeter. Evidence that this is possible in principle is the physiological investigation of the canine sense of smell. Dogs can detect and recognize odors carried by infinitesimal traces of organic molecules in the air, even in concentrations of 10^{5}-10^{6} molecules per cubic centimeter.

It scarcely needs explaining that the capability of detecting impurities contained for example in air in such minute concentrations opens up completely new possibilities for an enormous variety of practical applications -- from criminology to medical diagnosis. In this area physicists are way ahead of their colleagues from other fields of scientific study. Physicists have developed precision methods and instruments for registration of elementary particles and many imperceptible processes associated with nuclear transformations. And there are reasons to expect that the next few years will bring further advances in the detection of structural formations on a much larger scale -- individual molecules. Great hope in this area are pinned on further development of methods of laser spectroscopy.



At the top -- simplified diagram of a conventional mass spectrometer, where the electron beam ionizes all components of the molecular mixture. At the bottom -- simplified diagram of photoionization mass spectrometer, where a laser beam with tunable frequency can selectively ionize molecules of a certain kind. This yields a set of mass spectra of the individual components of the mixture rather than an integrated spectrum.

The most promising technique for detecting molecules in low concentrations is a photoionization method modeled on that described above for detecting individual atoms (see the color insert). Upon excitation by laser beams, the molecules are ionized by detachment of an electron, by dissociation of the molecule into separate fragments. To increase the analytical capabilities of the method, it is convenient to unify selective photoionization of molecules with mass spectroscopy. In doing so, instead of the conventional ionization of molecules by an electron beam that acts more or less identically on all molecules, a laser beam is used for selective ionization of only a single kind of molecule. And the mass spectrometer has only to perform the function of analyzing the spectrum of masses of molecular ions and fragments of molecules. Thus we arrive at the idea of a two-dimensional optical mass spectrometer whose working principle is explained in the diagram. The instrument measures the dependence of photoionic current on infrared laser frequency. Upon each coincidence of laser frequency with the natural frequency of one of the possible vibrations of the molecule, these vibrations are pumped up and there is a corresponding increase in the probability of photoionization of molecules. We get an energy spectrum of the molecules that reflects their structure. At the same time, just as should take place in the mass spectrometer, the spectrum of masses of the molecules is measured, and thus we have a supplementary analysis of the composition of the initial substance.

Experiments that have been done in recent years at the Institute of Spectroscopy of the USSR Academy of Sciences on selective excitation and ionization of complex molecules by laser radiation have provided basic principles for development of a laser detector of record-breaking low traces of organic molecules comparable in effectiveness of perception with the organs of smell of men and animals.

NARROW MOLECULAR RESONANCES -- THE BASIS OF OPTICAL QUANTUM METROLOGY

The motions of electrons in atoms and the vibrations of atoms in molecules are periodic processes with exceptionally constant period. Since the inception of quantum electronics this feature has been utilized for precise measurement of time and length. The entire world is on an atomic time standard in which the "swinging pendulum" is one of the periodic motions of the electron in a free atom of cesium. The error of the atomic time standard is now a few parts in 10^{-12}, which corresponds to an error of a few seconds in a hundred thousand years. The time interval and frequency of vibrations are now the most precisely measurable physical quantities.

The possibility of using the internal periodic motion of electrons in an atom as a "pendulum" is based on the fact that the atom resonates extremely sharply to an electromagnetic field of a definite frequency. Until recently, atomic clocks used resonant phenomena in the microwave band. Many new possibilities for metrology opened up when it became possible to tie in a laser frequency as well to highly stable atomic or molecular "pendulums." Unfortunately, optical resonances, i. e. optical spectral lines, are too broad to attain a laser frequency stability comparable to that of the cesium standard. The fact of the matter is that even in a gas, where the spectral lines are narrowest, atoms and molecules are constantly moving, and as a result of the Doppler effect, the frequency of radiation of these moving atoms (molecules) is slightly altered. We get what is called Doppler broadening of the spectrum, and the frequency of vibrations of the standard "pendulum" can now "wander" within the limits of this broadening.

More than ten years ago, physicists at the Institute of Semiconductor Physics of the Siberian Department of the Soviet Academy of Sciences and the Academy's Institute of Spectroscopy discovered properties of the interaction of light with atoms and molecules such that they were able to eliminate the effect of motion of particles on the frequency of optical resonances. Quite effective methods were developed for penetrating inside of broadened spectral lines and getting extremely narrow, or as they are called "high-Q" resonances in the optical band. This has been the basis of birth of a new area in spectroscopy -- ultrahigh-resolution nonlinear laser spectroscopy, principally the creation of Soviet scientists.

By the resolution of a spectral method we mean the capability to distinguish, or as we say to "resolve" two spectral lines with minimum spacing. At present the resolution of the best nonlinear laser spectrometers is nearly a million times the maximum resolution of linear devices limited by broadening of spectral lines. In particular, at the Siberian Department of the USSR Academy of Sciences a unique nonlinear laser spectrometer has been made that is based on a helium-neon laser with frequency stabilized by one of the vibrational-rotational motions of methane. The Doppler broadening of absorption lines of methane on vibrational-rotational transitions in the wavelength region of 3.39 μm (corresponding to a frequency of 10^{11} kHz) is 300,000 kHz. This laser spectrometer has attained the highest resolution of spectral measurements in optics: resonant peaks have been registered that are 1 kHz apart.

The discovery of methods of obtaining nonlinear narrow resonances in the optical band automatically has put into the hands of physicists atomic and molecular frequency standards of high frequency stability to which the laser frequency can be "tied". Such narrow nonlinear resonances have now been used to stabilize the frequency of many lasers in the infrared and visible region of the spectrum. The best results have been attained by the above-mentioned narrow nonlinear resonance obtained on the absorption line of the methane molecule in the vicinity of the wavelength of 3.39 μm: stability and reproducibility of laser frequency of better than 10^{-11} percent. A unique facility at the Institute of Thermal Physics of the Siberian Department of the Soviet Academy of Sciences has attained a record-breaking long-term frequency stability on a similar laser: the laser frequency of 10^{14} Hz varied on the average by no more than 0.5 Hz, and the spectral linewidth of the radiation was only 7 Hz. This laser is the most monochromatic source in the entire enormous range of electromagnetic oscillations mastered by present-day technology.

The development of lasers with high frequency stability can be considered a fundamental advance in many respects. First of all, such a laser, in contrast to a frequency-stable microwave oscillator, can serve simultaneously as a standard of both frequency (time) and length. The smallness of a wavelength of light as compared with the dimensions of the instrument enables precision measurements of length by interference methods. In this way the foundation is laid for a new area in metrology: quantum optical metrology. Another very interesting possibility is the measurement of periods of molecular vibrations in units of an atomic time standard. This means that in effect such a high-frequency time standard as a cesium clock can be used for practical measurement of the frequency of laser radiation (which is tied to molecular vibrations). In the final analysis this enables comparison of the atomic and molecular time scales established by science. Last summer in joint experiments of the All-Union Scientific Research Institute of Physicotechnical and Radiotechnical Measurements of the Soviet Bureau of Standards and the Institute of Spectroscopy of the Soviet Academy of Sciences, the frequency of vibrations in the osmium tetroxide molecule was measured in units of the cesium time standard with previously unattainable precision — with an error of no more than a billionth of one percent. We can realistically expect a further improvement in accuracy by a factor of tens.

With the capability of measurements of this kind, physicists are on the point of answering a fundamental question: are the so-called "universal constants", and specifically the charge and mass of electrons and protons, really constant? According to a hypothesis of Paul Dirac, because of the unsteady nature of the universe these constants may change with time by an infinitesimal amount of the order of a trillionth part per year. If this is so, then these changes can be detected in a laboratory experiment by comparing atomic and molecular time scales with the same accuracy since the universal constants affect the periodic motion of electrons in the atom and of the atoms themselves in the molecule in different ways. This is still another example of the far-reaching interrelationship between applied and fundamental research: after developing new methods for practical metrology, physicists make use of the instruments where these new methods are realized in solving their own fundamental problems.

INTENSE INFRARED RADIATION SELECTIVELY DESTROYS MOLECULES

A powerful laser pulse with frequency tuned to resonance with molecular vibrations causes them to be strongly pumped up. A molecule is capable of absorbing several dozens of quanta, and as a result the total energy of its oscillations may exceed the energy of interatomic bonds in the molecule -- the molecule disintegrates into individual fragments, or dissociates. It is most important that upon irradiation of a mixture of different substances, the strong pumping of oscillations and dissociation into fragments take place only for a single kind of molecules whose vibrations have fallen into resonance with the frequency of laser emission. In other words, by changing the frequency of laser radiation we can cause pumping up of vibrations and dissociation of molecules of a given type at will. This interesting phenomenon -- many-photon selective dissociation -- was discovered at the Institute of Spectroscopy of the USSR Academy of Sciences several years ago, and is now being actively studied and utilized in many laboratories throughout the world. The interest in many-photon dissociation is due to the high degree of selectivity in destruction of molecules hitherto unattainable by any other methods. In particular the possibility of isotope separation is based on this high selectivity.

Molecular vibrations are very sensitive to the isotopic makeup of the atoms in the molecule. Molecules with heavier isotopes vibrate somewhat more slowly than those with lighter isotopes. The frequency of the laser beam can be selected so that it resonates with the required isotope, thus enabling separation of isotopes. Many techniques for laser separation of isotopes have been discovered and developed in our nation. And today facilities that are acknowledged as satisfying the practical requirements for some isotopes are already operating on the basis of these methods. As a particular instance, an experimental facility has been made for producing the rare carbon isotope C^{13}, and work is now in progress on making a similar experimental industrial facility.

Methods of selective action of laser radiation on matter provide the basis for developing some fundamentally new processes. In particular, laser beams can be used to manipulate atoms and molecules of a definite kind, separating, sorting and collecting appreciable quantities of substance literally with respect to a single atom or a single molecule. The latter opens up interesting possibilities in such an important area as producing exceptionally pure materials, alloys and molecular compounds. The first successful experiments have already been done on deep laser purification of matter in the gaseous phase with respect to undesired molecular impurities. Entirely new possibilities in precision chemical technology have opened up on this path.

PICOSECOND LASER PULSES, AND BIOMOLECULES

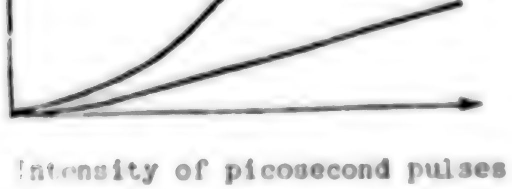
In the world of molecules, complex processes take place in billionths of a second, also involving absorption of light, conversion of luminous energy to the energy of chemical bonds, liberation of accumulated energy and so on. As examples familiar to everyone we can cite the processes of photosynthesis in plants and the processes in the visual organs of humans and animals.

Until recently, information on ultrafast processes of this kind in molecules was obtained exclusively by indirect means based on construction of a variety of models and hypotheses and subsequent comparison with experimental data.

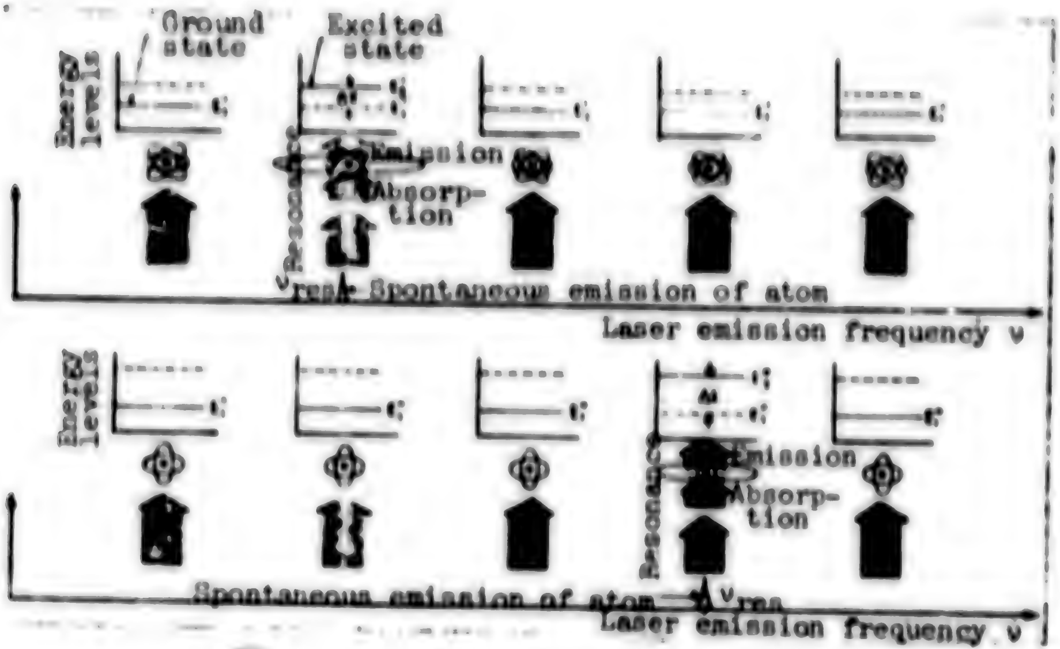
In recent years the possibility has opened up for direct study of ultrafast molecular processes that occur in time intervals measured in picoseconds (1 ps $= 10^{-12}$ s), i. e. in trillionths of a second. To get an idea of such a time interval, just think that light travels only one-third of a millimeter in a picosecond. A new possibility for studying ultrafast phenomena is based on using laser pulses of extremely short duration. Let us note that until recently electronic engineering held a kind of record in switching speed: an abrupt change in current could be produced in electronic circuits within a billionth of a second, i. e. in a nanosecond. Now the light emitted by a laser can easily change its intensity a thousand times faster, and the fastest processes controllable by man are laser light processes.

Because luminous energy is pressed into ultrashort laser pulses in extremely small time intervals, these pulses have very high power (up to a gigawatt) at comparatively low pulse energy (of the order of micro- and millijoules). Such powerful pulses can rapidly cause strong excitation of molecules and rupture of molecular bonds -- they have time to travel to the point where the molecule loses its acquired energy.

Among the most complicated objects of the microcosm are biomolecules that routinely contain thousands or millions of atoms. Despite their exceptional complexity, they are built up of a limited number of repeated microblocks that contain tens or hundreds of atoms. Resonant irradiation of biomolecules with laser pulses of picosecond duration selectively stimulates certain microblocks of the biomolecule. In the first place, this can help to understand in greater depth the true nature of processes such as photosynthesis, where there are important stages taking place in the first instants after absorption of a photon. In the second place, a laser pulse of ultrashort duration with definite wavelength is capable of selective destruction of certain segments of a biomolecule, which was recently demonstrated in joint experiments of the Institute of Spectroscopy together with the Institute of Bioorganic Chemistry and the Institute of Molecular biology of the USSR Academy of Sciences. In



Experiments on photochemical dissociation of the components of nucleic acids -- nitrogen bases -- under the action of picosecond light pulses have shown that different nitrogen bases have different photochemical stabilities. This opens up the possibility of selective action on the different kinds of bases that make up nucleic acid molecules.


Ground state
Excited state
Energy levels
Emission
Absorption
Resonance
ν_{res}
Spontaneous emission of atom
Laser emission frequency ν
Energy levels
Emission
Absorption
Resonance
Spontaneous emission of atom
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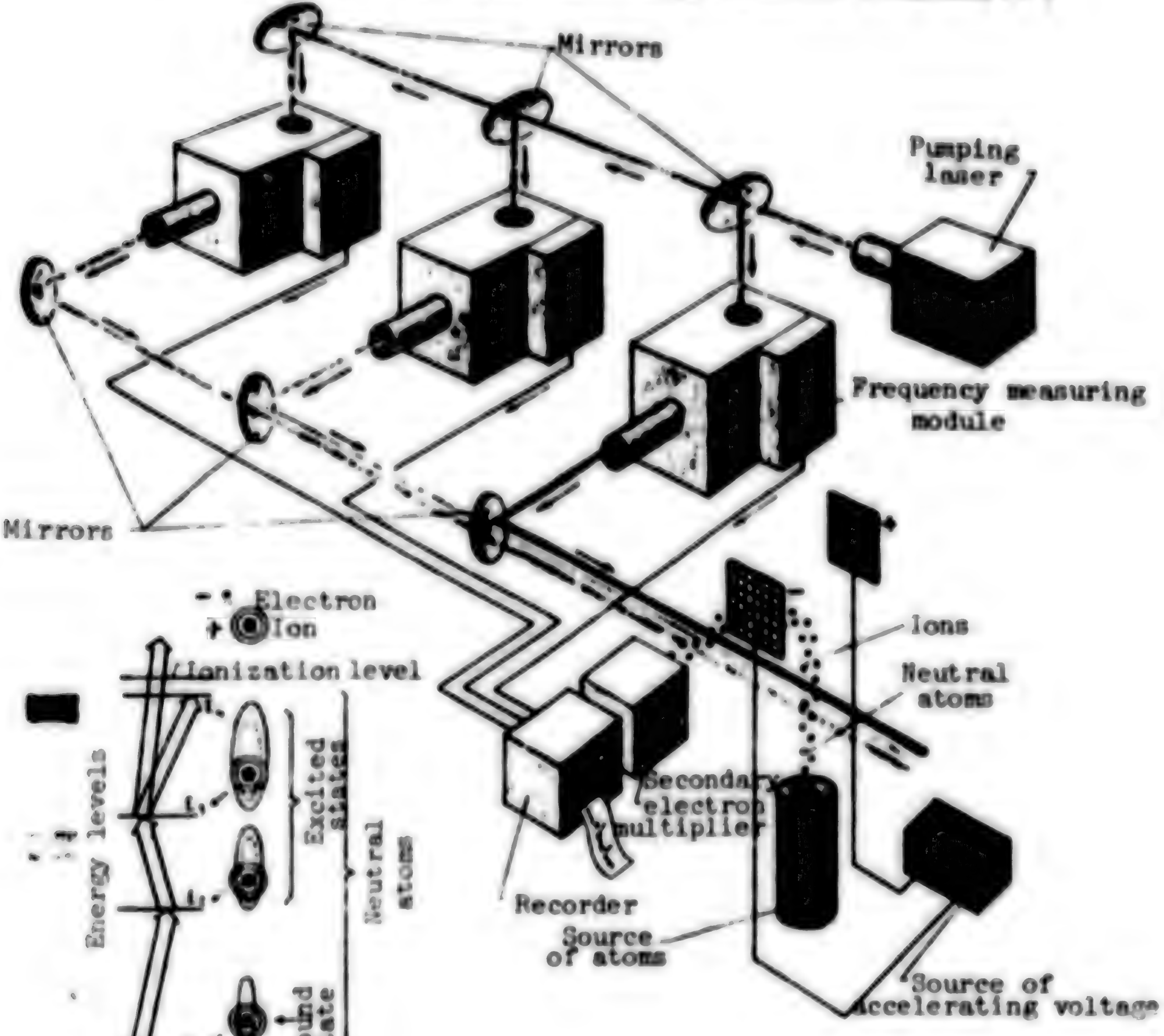
Laser emission frequency ν


Mirrors
Pumping laser
Frequency measuring module
Mirrors
Electron
Ion
Ionization level
Excited states
Neutral atoms
Energy levels
Ground state
Ions
Neutral atoms
Secondary electron multiplier
Recorder
Source of atoms
Source of accelerating voltage

these experiments, picosecond laser pulses with wavelength of 265 nm acted on the microblocks (bases) of the DNA molecule. Each of the blocks of the molecule is capable of successively absorbing two ultraviolet photons, which can lead to dissociation of the excited block. The probability of absorption of two photons is different for different blocks, despite the identical probability of absorption of the first photon. This gives a certain possibility for selective destruction of molecules. Moreover the probability of destruction of a molecule that has absorbed two photons is much greater than with absorption of one photon. In this connection it is of interest to investigate the intentional use o. frequently repeated ultrashort pulses instead of continuous irradiation in photobiology and photomedicine. For example there are reasons for believing that ultrashort pulses may give a much greater therapeutic effect even with a considerable reduction in the overall dose of irradiation.

It can also be expected that the development of experiments in this area will lead to techniques for fairly selective action on certain blocks of the DNA molecule to get intentional mutations. But even if this remarkable goal is not attained, the selective action by laser emission on the DNA base may open up a new possibility for development of a physical method of direct reading of genetic information.

Of course, this is the most complicated of all the problems that physicists are now trying to solve in the field of selective action by a laser beam on atoms and molecules. Nevertheless, physicists are optimistically looking forward to solving it along with other complicated problems. Advances of recent years in the field of studying and using selective interaction of laser radiation with atoms and molecules, the fundamental scientific results that have been obtained in this field, the numerous instruments and devices actually based on successful fundamental research, the variety of realistic approaches to problems as yet unsolved, and the considerable interest in this area shown by up-and-coming scientists all taken together gives us the right to hope for considerable achievements in the future.

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[illegible]
CSO: 5144/0844

UDC 621.378.35

THERMAL RESISTANCE OF (Al, Ga)As HETEROSTRUCTURE LASERS WITH STRIP CONTACT

Minsk IZVESTIYA AKADEMII NAUK BSSR: SERIYA FIZIKO-MATEMATICHESKIKH NAUK
in Russian No 4, Jul-Aug 80 pp 66-69 manuscript received 28 Sep 79

POLYAKOV, M. Ye., Institute of Physics, BSSR Academy of Sciences

[Abstract] The thermal resistance of a double-heterostructure (Al, Ga)As laser with strip contact is calculated, and some ways to reduce thermal resistance are suggested. The analysis is based on solution of approximate equations for spread of the heat flux, assuming that the material of the layers is isotropic and homogeneous, disregarding heat exchange between the diode and the ambient medium as well as Joule losses. The heat source is assumed to be planar and located in the middle of the active medium parallel to the plane of the p-n junction. It is shown that a transition from a strip contact to a wide contact is accompanied by a slight reduction in thermal resistance. Fastening to the heat sink by the p-region reduces the thermal resistance by a factor of 10.6 as compared with fastening by the backing for a diode with a wide contact when the p-(Al, Ga)As and p-GaAs layers are 2.5 μm thick. Thermal resistance decreases as the width of the diode increases. It is found that the temperature of the active region is considerably dependent on the parameters of the heat sink. It is concluded that the service life of heterostructure lasers can be extended by making wide diodes with thin emitters, and by fastening the p-region of the diode to the heat sink. The author thanks A. S. Rubanov for constructive discussions. Figures 2, references 14: 5 Russian, 9 Western.
[69-6610]

UDC 535.343+535.372

SPECTROSCOPIC AND EMISSION CHARACTERISTICS OF AN ALEXANDRITE (Be, $Al_2O_3:Cr^{3+}$) LASER

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 256, No 2, 1981 pp 373-376
manuscript received 18 Sep 80

SEVAST'YANOV, B. K., REMIGAYLO, Yu. L., OREKHOVA, V. P., MATROSOV, V. P., TSVETKOV, Ye. G. and BUKIN, G. V., Institute of Crystallography imeni A. V. Shubnikov, USSR Academy of Sciences, Moscow, Institute of Geology and Geophysics, Siberian Department, USSR Academy of Sciences, Novosibirsk

[Abstract] In line with recent research on alexandrite as a new laser material, the authors present results of measurements of the spectroscopic and lasing properties of alexandrite crystals grown by the Czochralski method using induction heating in iridium crucibles in a controlled inert atmosphere. The seed crystals were oriented in directions [100], [010] and [001]. The crystals used in the lasing experiments were optically homogeneous cylinders up to 6 mm diameter and 70 mm long with the geometric axis oriented in direction c and chromium concentration of 0.03 mass percent. Absorption spectra taken at 77 K showed 5 times the intensity of lines R_1 and R_2 as compared with measurements at room temperature, and displacement of the lines into the short-wave region by 8 Å. With a reduction in temperature an intense narrow line shows up at 643.5 nm in the absorption spectrum in polarization $E \parallel b$. This line cannot be seen in the luniescence spectrum, and it disappears in the absorption spectrum at room temperature. The same line can be observed in the R_1 excitation spectrum, and it is attributed to the phononless electron transition $^4A_2 \rightarrow {}^4T_2$. Tunable lasing from 700 to 800 nm was achieved at room temperature. The temperature dependence of the lasing threshold reaches a minimum at 70°C. The authors thank Academician B. K. Vaynshteyn and Professor A. A. Godovikov for interest in the work. Figures 4, references 11: 6 Russian, 5 Western.
[83-6610]

UDC 621.378

SOME PROBLEMS OF DURABILITY OF HELIUM-CADMIUM LASERS

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 33, No 5, Nov 80 pp 822-827
manuscript received 31 Jan 80

GRISHIN, N. I., DYATLOV, M. K., KAS'YAN, V. G. and LEVIN, V. G.

[Abstract] Previous research has shown that the main factor limiting service life of helium-cadmium lasers is helium sorption that accompanies cadmium deposition on cold parts of the active element. Cadmium fogging of the optical windows is negligible in the absence of temperature and electric field gradients. The durability of such lasers has been increased by an order of magnitude, to 1000-2000 hours, by using discharge tubes in which cadmium settles out on a condenser and the polarity

of the discharge is periodically reversed so that the cadmium is revaporized and the sorbed helium is released into the discharge. Since metal-vapor lasers with even longer service life are now needed, the authors investigate the processes in helium-cadmium lasers that limit durability of the active element with 3000-5000 hours of operation. It is found that the principal factor leading to power reduction after several thousands of hours of duty is loss of reflective properties by the mirrors due to discharge emission and deposition of cadmium vapor. After 3000 hours of operation, power reduction is partly due to a decrease in helium pressure and the release of impurities from dissociation of the glass capillary. One of the main processes that cause fogging of the mirrors is luminous pressure inside the optical cavity, which has a more pronounced effect on the output mirror than on the opaque mirror. For a power of 50 mW and particle size of 0.01 m the force of the luminous pressure is $1.3\cdot10^{-20}$ N, which is comparable to the force of gravity acting on these particles ($0.44\cdot10^{-20}$ N). Figures 4, references 5 Russian.
[88-6610]

UDC 621.375

ENERGY CHARACTERISTICS OF GASDYNAMIC LASERS WITH TELESCOPIC RESONATOR

Novosibirsk FIZIKA GORENIYA I VZRYVA in Russian Vol 16, No 2, Mar-Apr 80 pp 73-78
manuscript received 12 Mar 79

KOZLOV, G. I. and SELEZNEVA, I. K., Moscow

[Abstract] An analysis is made of the energy characteristics of gasdynamic lasers with unstable telescopic cavity utilizing a five-component active mixture containing CO_2, N_2, CO, H_2O and H_2. An investigation is made of the way that efficiency, power and the distribution of radiation depend on the parameters of the cavity and of the stream of gas with consideration of the principal channels of collisional relaxation. Optimum working conditions for lasers of this type are discussed, and it is shown that the optimum parameters of the cavity are not the same for efficiency and power as for directionality of radiation. To maximize efficiency and power, cavities with low magnification should be used. The magnification must be maximized for high directionality of radiation. The proper compromise depends on the requirements to be met by the laser output. Figures 6, references 10: 9 Russian, 1 Western.
[74-6610]

UDC 621.378

INDUCED LOSSES IN A FLASH-PUMPED RHODAMINE-6G DYE WAVEGUIDE LASER

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 32, No 5, May 80 pp 933-936
manuscript received 24 Aug 79

NENCHEV, M. N., Institute of Electronics, Bulgarian Academy of Sciences, Sofia

[Abstract] Among the main sources of induced losses in dye lasers are optical distortions of the active medium induced by the pumping radiation, such losses being appreciably dependent on the type of optical cavity that is used. This paper is a report on experimental investigation of induced losses in a cavity waveguide type rhodamine-6G dye laser with flashlamp pumping. Induced losses were determined by comparing lasing power thresholds (pumping power at the instant of lasing onset) in two pumping pulses, either superimposed or sequential. Losses due to induced optical inhomogeneities are much lower than in a plane-parallel Fabry-Perot cavity. Periodic pulsations of emission due to generation of acoustic waves are observed at high pumping energies. The author thanks A. M. Korobov for discussing some of the preliminary results. Figures 2, references 10: 7 Russian, 2 Bulgarian, 1 Western.
[92-6610]

UDC 621.375.8

CONDITIONS OF STIMULATED EMISSION OF SHORT PULSES IN LASERS WITH NONLINEAR DELAYED ACTION ELEMENT

Minsk ZHURNAL PRIKLADNOY SPEKTROSKOPII in Russian Vol 34, No 2, Feb 81 pp 209-215

SAMSON, A. M. and LOYKO, N. A.

[Abstract] The text of a paper presented at the Second All-Union Conference on Laser Optics held in Leningrad, 4-8 January 1980. An investigation is made of the effect that introducing a nonlinear delayed action element in a laser cavity has on the fine time structure of the emission when the coefficient of losses of the nonlinear element depends on the density of laser emission at a preceding instant. Such an element may be a shutter (for example a Kerr cell) controlled by stimulated emission transmitted through an external electronic device. It is shown that such a system is theoretically capable of generating a stable and reproducible sequence of subnanosecond pulses. The analysis is based on differential equations with a delayed argument for radiation density and gain. An expression is found for the period of high-frequency pulsations as a function of the system parameters. The controlling factor in this case is the delay time of response of the nonlinear element to the radiation field. Conditions are found for optimization of high-frequency pulses up to degeneration to a series of short pulses. Results of numerical modeling of the lasing process are given. Figures 3, references 6 Russian.
[99-6610]

ABSORPTION AND SCATTERING OF RADIATION BY A PLASMA FROM PICOSECOND RUBY LASER PULSES

Moscow ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 80, No 1, Jan 81 pp 144-160 manuscript received 8 Jul 80

BLAZHENKOV, V. V., KIRKIN, A. N., KONONOV, A. V., KOTENKO, L. P., LEONTOVICH, A. M., MERZON, G. I. and MOZHAROVSKIY, A. M., Physics Institute imeni P. N. Lebedev, USSR Academy of Sciences

[Abstract] An experimental investigation is made of optical and x-ray emission of a plasma produced by picosecond pulses from a ruby laser at flux densities ranging from 10^{13} to $5\cdot10^{14}$ W/cm^2. The results are used for calculating the plasma parameters and determining the principal mechanisms of absorption of laser radiation by the plasma. It is shown that the coefficient of absorption is 70-90%. There is a low proportion of induced Mandelstam-Brillouin scattering in the overall energy balance. The spectrum of the scattered optical and x-ray emission is studied as well as the spatial and angular distribution, and also the polarization of cw x-radiation of the laser plasma. It is shown that the principal anomalous mechanism of absorption responsible for production of epithermal neutrons is resonant absorption. The authors thank M. G. Galanin for interest, G. A. Askar'yan and S. D. Zakharov for discussing the results, and also R. G. Mirzoyan for assistance. Figures 12, references 44: 16 Russian, 28 Western.
[68-6610]

UDC 621.385.6

DESIGN OF A THREE-ELECTRODE ELECTRON GUN FOR PRODUCING A HELICAL ELECTRON BEAM IN A TUNABLE CYCLOTRON RESONANCE MASER

Moscow VESTNIK MOSKOVSKOGO UNIVERSITETA, SERIYA 3: FIZIKA, ASTRONOMIYA in Russian Vol 22, No 1, Jan-Feb 81 pp 42-46 manuscript received 11 Dec 78

KOROLEV, F. A., ABDULKAIROV, F. M. and TULUPOV, A. V.

[Abstract] A method is proposed for calculating a three-electrode optoelectronic system for shaping helical electron beams. The proposed gun is intended for use in cyclotron resonance masers with tunable output frequency to optimize the ratio of transverse to longitudinal electron velocity as the magnetic field varies. The calculations take consideration of the distribution of electric fields between the electrodes of the system. The effect of space charge is disregarded. The process of electron motion from the instant of leaving the cathode surface to arrival in the resonator is divided into four stages, each one being characterized by different expressions for the electric and magnetic field strength. The ratio of rotational energy of the electron to translational energy is calculated for different voltages across the electrodes and different magnetic field intensities in the interaction space on the basis of solution of the equation of motion. Figures 4, references 4 Russian.
[100-6610]

UDC 621.378.325

STIMULATED EMISSION OF STEADY-STATE ULTRASHORT RADIATION PULSES IN LASERS WITH OPPOSED WAVES

Minsk DOKLADY AKADEMII NAUK BSSR in Russian Vol 25, No 2, Feb 81 pp 124-127
manuscript received 18 Jun 80

KOTOMTSEVA, L. A., LOYKO, N. A. and SAMSON, A. M., Institute of Physics,
BSSR Academy of Sciences

[Abstract] The authors investigate the conditions of stimulated emission of ultrashort pulses of radiation in a laser with opposed waves. The traveling-wave approximation is used in description of the laser on the basis of semiclassical equations It is shown that the development of pulsations is due to coincidence of the frequency of oscillations in gain and the frequency of intermode beats, and the steady-state nature of the pulses is due to dispersion of the active medium. An ultrashort pulse train in such a laser can be produced either by the development of nutational vibrations or by the interaction of opposed radiation fluxes. It is suggested that self-mode locking in ruby and YAG:Nd lasers is due to these mechanisms. Figures 2, references 9: 6 Russian, 3 Western.
[101-6610]

UDC 539.14

OBSERVATION OF MAGNETIC RESONANCE SIGNALS WITH LASER PUMPING

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 256, No 2, 1981 pp 368-369
manuscript received 23 Jul 80

IYEVSKAYA, N. M., KORNIYENKO, L. S., KOTKIN, A. L. and UMARKHODZHAYEV, R. M.,
Scientific Research Institute of Nuclear Physics, Moscow State University
imeni M. V. Lomonosov

[Abstract] Previous research has demonstrated the feasibility of pumping the sublevels of the ground state of ^{133}Cs atoms by using a semiconductor injection laser. This paper gives the results of research on using semiconductor lasers to set up a population differential between Zeeman sublevels of the ground state. The working fluid was ^{133}Cs vapor pumped and probed by frequency-stabilized homostructure GaAs lasers. Laser operation was cw single-mode at nitrogen temperatures. Information was extracted by nonresonant light by using the Faraday effect, thus giving intense magnetic resonance signals with relaxation times practically equal to the dark times. This technique makes it possible to pinpoint the center of the magnetic resonance line with precision at least two orders of magnitude improved over the accuracy attained with gas-discharge spectral lamps. The proposed pumping method can be used for materials that do not have a singlet ground state. Figures 2, references 3: 1 Russian, 2 Western.
[83-6610]

MAGNETOHYDRODYNAMICS

GENERATION OF A QUASISTATIC MAGNETIC FIELD IN A PLASMA BY AN INTENSE ELECTROMAGNETIC WAVE

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian
Vol 33, No 3, 5 Feb 81 pp 160-163 manuscript received 20 Dec 80

BRODSKIY, Yu. Ya., ZHAROV, A. A., NECHUYEV, S. I. and SLUTSKER, Ya. Z.,
Institute of Applied Physics, USSR Academy of Sciences

[Abstract] Arisal of a quasistatic magnetic field upon interaction of intense radiation with plasma was first observed in laser-driven fusion experiments. Experimental results have been interpreted in terms of known mechanisms: electron entrainment due to transfer of momentum from the electromagnetic wave to the electrons upon absorption in the plasma, and also the excitation of current due to the nonparallelism of $\vec{\nabla} n$ and $\vec{\nabla} T_e$. The experiments described in this paper were initiated by research in which intense anisotropic fluxes of accelerated electrons were observed with preferred direction along the electric field of the incident wave. A plasma layer was set up inside a vacuum chamber, and an electromagnetic wave in the 10-cm band was incident on this layer from the open end of a waveguide on the axis of the layer. The quasistatic magnetic field was measured by a shielded coil. Current in the plasma was measured by a Rogowski loop. The results show that the field has an octupole structure, and is produced by the current of electrons excited by the microwave field. The authors thank N. G. Kondrat'yev, A. G. Litvak and M. A. Miller for discussion, and Ye. I. Rakova for assistance in processing the experimental data. Figures 2, references 7: 2 Russian, 5 Western.
[70-6610]

SHAPED-CHARGE GENERATION OF HIGH-POWER ELECTRIC PULSES

Novosibirsk FIZIKA GORENIYA I VZRYVA in Russian Vol 16, No 5, Sep-Oct 80 pp 47-56 manuscript received 2 Apr 80

TITOV, V. M. and SHVETSOV, G. A., Novosibirsk

[Abstract] A study was made of an MHD pulse generator with cumulative gas jets formed by detonation of tubular explosive charges in a cylindrical bundle and flowing between plane parallel electrodes in a transverse magnetic field. The

flowing between plane parallel electrodes in a transverse magnetic field. The theoretical performance analysis is based on the equation of motion and on the relations in an inductive-resistive electric circuit. The experimental performance analysis is based on measurements of the velocity of shock waves and on calculation of the efficiency of chemical-to-kinetic energy conversion, both under atmospheric ambient pressure and both depending on the ratio of outside to inside charge diameter and on the distance from the charge to the MHD channel. The results indicate that an explosive forms an active inner core and a passive outer shell, the thickness of the latter being minimum in a "cellular" charge structure but not smaller than some critical thickness. The experiments were performed with two linear MHD channels 18 x 35 mm^2 in cross section, one 300 mm and one 500 mm long. Conversion of kinetic energy to electric energy produced pulses of up to 920 kA and 37 kJ, with the length-to-diameter ratio of the tubular charges inside a common steel cartridge varied from 20 to 7. The pulse duration did not depend on the initial magnetic field intensity, with the magnetic induction in the channel varied from 5 to 25 T, and the velocity of gas jets remained almost constant throughout the entire channel length. The authors thank Yu. A. Burenin for assisting with the numerical computations. Figures 9; references 15: 8 Russian, 7 Western.
[107-2415]

UDC 538.4

SOME UNSTEADY TURBULENT MHD FLOWS IN FLAT CHANNELS AND CIRCULAR PIPES

Riga MAGNITNAYA GIDRODINAMIKA in Russian No 2, Apr-Jun 79 pp 46-50
manuscript received 19 Jul 77

NEMIROVSKIY, Yu. V. and KHEYNLOO, Ya. L.

[Abstract] An analysis is made of the kinematic characteristics of turbulent pulsating flow of an electrically conductive fluid in a flat channel and in a circular pipe in longitudinal and azimuthal magnetic fields. It is assumed that walls are impermeable, and that all averaged flow characteristics depend only on the transverse coordinate in accordance with the equation of continuity (the medium is taken as incompressible) and equations of motion of electrically conductive media. Disregarding the Hall effect, a system of equations is derived for the averaged velocity components and the motion of the medium. The calculations are based on a semiempirical method developed by the authors. The theoretical results agree satisfactorily with experimental data. The authors thank V. M. Bukreyev and V. M. Shakhin for supplying additional experimental data. Figures 2, references 4 Russian.
[56-6610]

UDC 538.4:536.25

STEADY-STATE MHD CONVECTION IN A VERTICAL ANNULUS IN A RADIAL MAGNETIC FIELD

Riga MAGNITNAYA GIDRODINAMIKA in Russian No 2, Apr-Jun 79 pp 27-34
manuscript received 25 Dec 78

KOLYSHKIN, A. A.

[Abstract] The stability of convective flow in a vertical annulus with constant vertical temperature gradient was studied previously by Sorokina and Chudinov [see A. I. Sorokina, A. A. Chudinov, "Free Steady-State Convection Between Two Vertical Coaxial Cylinders", UCH. ZAP. PERMSKOGO UN-TA, Vol 9, No 4, 1955, pp 49-60]. Kolyshkin now generalizes this work to the MHD case of motion of a conductive liquid in a vertical annulus in a radial magnetic field $B^e = (B_0R_1/r, 0, 0)$. Flow is analyzed in the region $R_1 \leq r \leq R_2$, $0 \leq \phi \leq 2\pi$,

$-\infty < z < +\infty$ (r, ϕ, z are cylindrical coordinates, the z-axis is directed upward, R_1 and R_2 are the inner and outer radii of the cylinders). The fluid is viscous and incompressible, and the heat flux is known on the walls of the annulus. Curves are plotted for the critical Rayleigh numbers as a function of the Hartmann number for different values of R_2/R_1. It is shown that a magnetic field appreciably increases motion stability at small values of this ratio, and has a weaker effect on stability at large values of R_2/R_1. Figures 2, references 3 Russian.
[56-6610]

MHD INSTABILITIES OF METAL JETS IN ARC MELTING

Leningrad ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 50, No 10, Oct 80
pp 2112-2119 manuscript received 27 Sep 79

PEREGUD, B. P. and PONEDILKO, S. V.

[Abstract] An examination is made of processes occurring in an electric arc furnace during melting of metal. A "crown" isfformed in the upper part of the ingot during the initial stage by conglomeration of metal droplets of a wide size range. The authors atrribute this effect to MHD instability of jets of molten metal closing the arc gap. The consumable electrode metal flows into the bath, small jets close the arc gap, and electric current starts to flow through these jets. Pinch and corkscrew instabilities break the jets up into droplets that are dispersed at high radial velocities, settling on the cool walls of the crystallizer, where they begin to solidify, and are then locally remelted by subsequent droplets, which merge with them to form the characteristic crown on the ingot. This hypothesis is confirmed by analysis of experimental data. The authors thank K. B. Abramova and V. B. Boshnyak for photographing the arc gap in infrared light. Figures 6, references 18 Russian.
[79-6610]

UDC 517.958:537.84

VARIATIONAL SCHEMES OF MAGNETOHYDRODYNAMICS IN AN ARBITRARY COORDINATE SYSTEM

Moscow ZHURNAL VYCHISLITEL'NOY MATEMATIKI I MATEMATICHESKOY FIZIKI in Russian
Vol 21, No 1, Jan-Feb 81 pp 54-68 manuscript received 13 Feb 80

GOLOVIZNIN, V. M., KORSHIYA, T. K., SAMARSKIY, A. A., TISHKIN, V. F. and
FAVORSKIY, A. P., Moscow

[Abstract] A variational principle analogous to the principle of least action in classical mechanics is used to construct difference schemes for three-dimensional MHD equations written in an aribtrary curvilinear coordinate system. The proposed approach automatically yields difference analogs of conservation laws. An examination is made of some of the properties of differential-difference equations of magnetohydrodynamics, and it is shown that they are totally conservative. Numerical examples are given. The authors thank M. Yu. Shashkov and V. A. Gasilov for their comments, and also B. Ya. Lyubimov for discussing the differential equations and making a number of constructive suggestions. Figures 3, references 14:
12 Russian, 2 Western.
[71-6610]

NUCLEAR PHYSICS

DETERMINING THE REGION OF NEUTRON PRODUCTION IN CHAMBERS WITH A PLASMA FOCUS

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 33, No 3, 5 Feb 81 pp 148-151 manuscript received 13 Dec 80

TRUSILLO, S. V., GUZHOVSKIY, B. Ya., MAKEYEV, N. G. and TSUKERMAN, V. A.

[Abstract] In 1976 the authors studied the dimensions of a neutron source in a plasma focus by a multislit collimator (raster) made up of parallel plates of transparent plastic. Neutron registration was by RT-2 film with two thin scintillator converters. The technique used enabled approximation of the size of the region of neutron generation (2-4 mm in diameter by 8-12 mm long) and the position of its center of gravity (about 12 mm from the anode). In this paper the authors describe experiments with a raster technique and camera obscura in which neutron diffraction patterns are obtained in the main measurements by using a high-efficiency bubble chamber with high spatial resolution. This experimental setup produced a quite satisfactory image of the neutron production region at a minimum flux density of $2\cdot10^3$ neutrons/cm^2 in the plane of the bubble chamber window. The region was small and elongated with transverse dimensions of no more than 2 mm and length from 5 to 12 mm depending on the discharge conditions. The center of gravity of the emissive region was on the axis of the chamber at a distance of 12 mm from the anode. The density of neutron emission drops off abruptly outside of this region, the main neutron yield (more than 90%) being due to processes that take place in the phase of maximum plasma compression. Figures 2, references 8: 3 Russian, 5 Western.
[70-6610]

UDC 539.188

HIGH-CURRENT ION BEAMS

Moscow USPEKHI FIZICHESKIKH NAUK in Russian Vol 132, No 1, Sep 80 pp 91-122

BYSTRITSKIY, V. M. and DIDENKO, A. N., Scientific Research Institute of Physics at Tomsk Polytechnical Institute imeni S. M. Kirov

[Abstract] A survey of research in the field of high-current ion beam generation in diode systems. The methods of beam generation covered include symmetric and

asymmetric reflex systems, the reflex triode with massive dielectric anode, magnetically isolated diodes with drift electron beam and with Larmor electron orbits, and diodes with pinching of the electron beam. Transporting and focusing techniques are also discussed: mechanisms of neutralization and transporting, ballistic and electromagnetic focusing. Potential applications are described, including ion-beam controlled nuclear fusion, ion rings for facilities of the Astron type, neutron sources based on high-current ion beams, and laser pumping. It is concluded that physical processes that occur in diode systems during formation of ion beams have been reasonably well covered by research, although further refinements are needed on various details such as motion of the electrode plasma in the anode-cathode gap and the part played by electrons scattered by the anode. The problems of transportation and focusing need much more work, and it is suggested that future research be concentrated in this area. Figures 15, references 125: 31 Russian, 94 Western.
[73-6610]

UDC 539.12

INVESTIGATION OF ELECTROMAGNETIC INTERACTIONS ON ELECTRON-PHOTON BEAMS OF PROTON ACCELERATORS

Moscow FIZIKA ELEMENTARNYKH CHASTITS I ATOMNOGO YADRA in Russian Vol 11, No 5, Sep-Oct 80 pp 1109-1159

GOVORKOV, B. B., Physics Institute imeni P. N. Lebedev, USSR Academy of Sciences

[Abstract] Methods are considered for producing electron-photon beams on high-energy proton facilities by using gamma quanta from decay of pseudoscalar mesons. When accelerated protons interact with nuclei, a cone of particles is produced with the axis in the direction of motion of the charged particle. Some of these particles are neutral mesons that decay into photon pairs. One method of getting a photon beam is to use these photons. A magnet system can separate the neutral and charged components of the beam. In a second technique, a converter of a heavy material is placed in the path of the gamma quanta, giving electron-positron pairs, from which an electron-positron beam can be produced by using magneto-optical channels. Another method is to use a converter radiator to get a system of electron-tagged photons. Experiments involving electromagnetic interactions on electron-proton beams are described for measuring the total cross sections of hadronic photoabsorption, photoproduction of vector mesons and charmed particles, and Compton scattering of photons. Figures 40, references 86: 16 Russian, 70 Western.
[64-6610]

FOCUSING AND CHANNELING NEUTRONS AND OTHER UNCHARGED PARTICLES IN A FERROMAGNETIC BY DYNAMIC AND STATIC METHODS

Moscow ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 79, No 2(8), Aug 80 pp 481-496 manuscript received 22 Jun 79, after revision 18 Mar 80

VYSOTSKIY, V. I. and KUZ'MIN, R. N., Kiev State University imeni T. G. Shevchenko, Moscow State University imeni M. V. Lomonosov

[Abstract] It is conventionally assumed that the channeling effect in crystals can be realized only for charged particles with purely Coulomb forces locking the particles in the channel. In this paper it is shown that effective channeling as well as concomitant focusing, monochromatization and polarization of the resultant beam can be accomplished in magnetic crystals for uncharged particles that have a magnetic moment. Containment forces are due to dipole-dipole interaction with ordered inhomogeneous distribution of the magnetic moments in the crystal. Since the interaction of neutrons with the spin or elastic waves of the ferromagnetic material is considerably weaker than Coulomb interaction, the frequency of oscillations and the angle of capture into the channeling mode are much lower than for conventional channeling. In addition to dynamic methods involving excitation of waves in the magnetic material, the authors also consider the way that particle motion in the channel is affected by the static domain wall. Under certain conditions, the channeled particle beam can be focused by a transition domain wall. A system of such walls (many-domain ferromagnetic) can act as an effective telescopic focusing system. Figures 4, references 7 Russian.
[95-6610]

UDC 539.121.7+539.121.8

FORMATION OF HIGH-ENERGY CHARGED PARTICLE BEAMS BY CRYSTALS

Moscow FIZIKA ELEMENTARNYKH CHASTITS I ATOMNOGO YADRA in Russian Vol 12, No 1, Jan-Feb 81 pp 220-263

FEDYANIN, V. K. and GAVRILENKO, G. M., Joint Institute of Nuclear Research, Dubna

[Abstract] A great deal of physical research is now being done on high-energy particles moving in crystals at small angles to the axes of planes of symmetry. Most of the physical effects that have been observed show a specific orientation dependence due to interaction of charged particles with the medium and anomalously low energy losses. This is attributed to a particular form of motion called "channeling". The authors study the feasibility of effectively forming beams of high-energy charged particles by crystals. A general scheme is proposed for describing channeled beams of high-energy charged particles in terms of emission of "Z-evolution" of a small subsystem in dynamic contact with a large system. An exact equation is derived for the independent-particle distribution function of particles in a beam with deep penetration into a crystal. The first two approximations of this equation are studied. It is shown that the function is related to the Lindhard continuum potential theory. An investigation is made of the asymptotic state of distribution of particles at great depths of penetration into the crystal. The effects of the shaping action that the crystal has on beams of high-energy protons and ions is discussed. Figures 9, references 30: 17 Russian, 13 Western.

[65-6610]

OPTICS AND SPECTROSCOPY

UDC 621.391.832.2.771.537

CORRECTION OF AN OPTICAL IMAGE BY PRELIMINARY DIFFERENTIATION

Minsk DOKLADY AKADEMII NAUK BSSR in Russian Vol 25, No 2, Feb 81 pp 128-131
manuscript received 26 Jun 80

DOVNAR, D. V. and PREDKO, K. G., Mogilev Department, Institute of Physics,
BSSR Academy of Sciences

[Abstract] The authors consider the problem of correcting an optical image distorted by linear homogeneous systems described by an integral equation of the first kind of convolution type, and find numerical solutions for this equation that are closer to the initial undistorted image than approximate solutions found by the method of regularization. It is assumed a priori that noise is uncorrelated in adjacent sections of the image. Differential image correction operators are constructed that are conditionally stable with respect to such noise. The error in use of such operators decreases with decreasing distances between readings in the image being analyzed. A numerical example is given showing the effectiveness of the proposed method of correction. Figure 1, references 6 Russian.

UDC 621.382.2

THEORY OF A pnpn-TYPE OPTOELECTRONIC POWER SWITCH

Leningrad FIZIKA I TEKHNIKA POLUPROVODNIKOV in Russian Vol 14, No 9, Sep 80
pp 1747-1755 manuscript received 26 Jun 79, after revision 31 Jan 80

GREKHOV, I. V. and YASSIYEVICH, I. N., Physicotechnical Institute
imeni A. F. Ioffe, USSR Academy of Sciences, Leningrad

[Abstract] A theory is constructed for a laser-controlled pnpn-type power switch. It is shown that in a certain range of plasma densities this switch behaves like a d-c resistor in which the carrier concentration is determined by illumination. The working process of the switch during exposure to laser light is analyzed, and the results are compared with experimental data. An examination is made of the behavior of the switch after the light source is extinguished and the system relaxes to the steady state where the plasma concentration in the central part of the pnpn-type switch is determined by the current flowing in the system. The authors study the problem of boundary conditions on the pn junction in high-current operation and derive new boundary conditions without the assumption of quasineutrality. The limits of applicability of the quasineutral approximation are determined. Figures 3, references 10: 8 Russian, 2 Western.
[78-6610]

PLASMA PHYSICS

TWO-DIMENSIONAL PLASMA WAVE INSTABILITIES

Moscow ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 79, No 2(8) Aug 80 pp 555-560 manuscript received 28 Dec 79

KRASHENNIKOV, M. V. and CHAPLIK, A. V., Institute of Semiconductor Physics, Siberian Department, USSR Academy of Sciences, Siberian State Scientific Research Institute of Metrology

[Abstract] An examination is made of the principal types of plasma instabilities in two-dimensional electron systems from the standpoint of amplifying two-dimensional plasma waves. Just as in the two-dimensional problem, wave instability may result from drift of one part of the plasma medium relative to another part. In the case considered, these two parts are spatially distinct, resulting in associated waves and possible amplification at certain drift velocities. Structures are considered that have already been realized, or can easily be realized experimentally: two thin parallel plasma layers separated by an intermediate dielectric, or a plasma layer above a conductive half-space. Criteria are found for onset of beam, kinetic and dissipative instabilities. Under certain conditions, these criteria are qualitatively different from their three-dimensional analogs. Critical drift velocities and increments of build-up of oscillations are calculated. Figures 2, references 10: 4 Russian, 6 Western.
[95-6610]

UDC 533.951

THE PROBLEM OF PARAMETRIC INSTABILITY OF A RELATIVISTIC PLASMA IN THE QUASILINEAR APPROXIMATION

Leningrad ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 50, No 10, Oct 80 pp 2066-2071 manuscript received 30 May 79, after revision 11 Nov 79

KERASHVILI, L. M. and POLADZE, Ts. D., Institute of Physics, GSSR Academy of Sciences, Tbilisi

[Abstract] The possibility of rf heating of a relativistic electron-ion plasma is investigated by using the effect of oscillation of the mass of the electron in an alternating electric field in combination with the quasilinear approximation

taken for explaining the conductive properties of the plasma. An analysis is made of some aspects of the plasma at relativistically high temperatures. The characteristics of high-frequency and low-frequency oscillations that are excited in the electron-ion plasma are studied. In particular, the authors calculate the work of the field over the plasma, the conductivity and the increment of instability in each of the investigated cases. The authors thank N. L. Tsintsadze for interest in the work and constructive suggestions. References 9 Russian.
[79-6610]

UDC 534.222.2:662.215

CONCERNING THE POSSIBILITY OF DISSOCIATION OF CAST TNT IN A COMPRESSION SHOCK

Novosibirsk FIZIKA GORENIYA I VZRYVA in Russian Vol 16, No 2, Mar-Apr 80
pp 92-99 manuscript received 20 Mar 79

TROFIMOV, V. S. and TROFIMOVA, G. P., Chernogolovka

[Abstract] One of the most important characteristics of the process of chemical transformation of an explosive is the rate of specific heat release $\dot{Q}_{p,v}$ normalized to conditions of constant pressure p and specific volume v. To process experimental data for information on the kinetics of this transformation under conditions of detonation, it is advisable to introduce another characteristic: $\dot{v} = v_0^2 G\dot{Q}_{p,v}/(vc^2)$, where G is the Gruneisen constant, v_0 and v are the initial and current specific volumes, c is the Lagrangian speed of sound defined by the expression

$$c^2 = -v_0^2\left(\frac{\partial p}{\partial v}\right)_{s,k}$$

, s is specific entropy, k is a variable (possibly multicomponent) that characterizes the chemical composition. The quantity $\dot{v}$ shows the relation between the rates of change in p and v in the adiabatic process

$$\frac{\partial v}{\partial t} = \frac{v_0^2}{c^2}\frac{\partial p}{\partial t} + \dot{v},$$

where the partial derivatives with respect to time t are taken at constant Lagrange coordinates. It is shown that it is possible in principle to use dynamic experimental data to construct an equation $\dot{v} = f(p, v, E)$ (where E is specific internal energy) or to make a decision about increasing the number of independent variables in this equation. The mere existence of this equation implies the feasibility of describing the transformation kinetics by a simple one-component equation of the form $\partial k/\partial t = F(p, T, k)$, where T is absolute temperature. The authors present a partial realization of this calculation of $\dot{v}$ immediately behind the shock front of a steady-state detonation in cast TNT from experimental data. It is shown that the reaction rate of dissociation depends on the parameter div $\vec{u}$. The authors thank A. N. Dremin for assistance, and S. A. Koldunov and K. K. Shvedov for providing oscillograms and for useful advice in discussing the work. Figures 2, references 20: 19 Russian, 1 Western. [74-6610]

UDC 539.377

STRESSED STATE OF TWO-LAYER ELASTIC BODIES

Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 39, No 4, Oct 80 p 756
manuscript received 7 Dec 79

LAKUSTA, K. V.

[Annotation of article deposited in the All-Union Institute of Scientific and Technical Information 18 Feb 80, registration No 1174-80 Dep]

[Abstract] The author considers the problem of two one-sided, one-dimensional bodies with different mechanical and thermal characteristics placed in contact along the base. The thermoelastic fields in the two-layer body are determined in the quasistatic and dynamic theories of thermoelasticity, assuming that temperature and displacement are known in each of the layers. The solution is found by Laplace transformation with respect to time. Investigation of the quasistatic temperature fields and stress fields shows that dynamic and quasistatic thermoelastic stresses coincide at time zero. References 2 Russian.
[69-6610]

SUPERCONDUCTIVITY

TWINNING PLANE OF A METALLIC CRYSTAL--A TWO-DIMENSIONAL SUPERCONDUCTOR

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian
Vol 33, No 3, 5 Feb 81 pp 167-170 manuscript received 8 Jan 81

KHAYKIN, M. S. and KHLYUSTIKOV, I. N., Institute of Physical Problems,
USSR Academy of Sciences

[Abstract] In previous research the authors observed and studied superconductivity of tin crystals arising at temperatures between T_c and T_c + 0.15 K at magnetic fields of less than 5 oersteds. Superconductivity was shown by the diamagnetic moment M_D and an increase in electrical conductivity of the specimen. It was assumed that the cause of the effect was development of superconductivity along dislocations. However, it was found that superconductivity was associated with the twinning plane rather than with dislocations. Tin crystals deformed so as to eliminate twinning showed no diamagnetic moment. It has also been experimentally shown that any possible concentration of impurities on the boundaries of crystals in the recrystallization process plays no part in this superconductivity effect. In this paper it is shown that the phenomenon can be explained by the novel concept of a "two-dimensional metal" formed by the crystal lattice of the twinning plane, a two-dimensional group of electrons moving parallel to the twinning plane, and two-dimensional phonons of the twinning plane. The authors thank P. L. Kapitsa for interest in the work, L. P. Pitayevskiy and V. S. Edel'man for discussion, and G. S. Chernyshev for technical assistance. Figures 2, references 5: 4 Russian, 1 Western.
[70-6610]

UDC 537.312.62+621.316.540

A SUPERCONDUCTIVE PULSE SOLENOID SWITCHED BY THE ELECTRIC EXPLOSION METHOD

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 256, No 5, 1981 pp 1119-1122
manuscript received 4 Aug 80

ANDRIANOV, V. V., BAYEV, V. P., LEBEDEV, S. V. and SAVVATIMSKIY, A. I.,
Institute of High Temperatures, USSR Academy of Sciences, Moscow

[Abstract] A promising method of rapid current switching in the excitation circuit of superconductive magnets is electric explosion of conductors. However,

in a typical electric explosion with products of high electric strength the current densities are so high that the time of metal heating before explosion is much shorter than the time of separation of the contacts of conventional mechanical circuit breakers. Reducing the current density to increase the heating time changes explosive action to fuse action with low electric strength of the products of wire destruction. The electric strength of the products of destruction can be substantially increased by enclosing the wire in a capillary tube of electrically nonconductive material. The high pressure of the incandescent wire and the material of the walls of the capillary prevents arcing. The authors propose a commutator consisting of a mechanical circuit breaker shunted by a wire enclosed in a capillary tube of quartz or glass sealed at the ends with thick walls to withstand the high pulse pressure. Experiments were done with this device used as a switch for a superconductive pulse solenoid. The results show that the proposed method is feasible. Figures 2, references 6 Russian.
[91-6610]

THEORETICAL PHYSICS

UDC 535.36

SCATTERING MATRIX FOR INTERACTION OF ELECTROMAGNETIC WAVES WITH ANISOTROPIC SPHERICAL PARTICLES

Minsk IZVESTIYA AKADEMII NAUK BSSR: SERIYA FIZIKO-MATEMATICHESKIKH NAUK in Russian No 4, Jul-Aug 80 pp 69-76 manuscript received 19 Nov 79

KUZ'MIN, V. N., Institute of Physics, BSSR Academy of Sciences

[Abstract] An analysis is made of the problem of scattering of electromagnetic waves by particles with dimensions of the order of a wavelength of the incident radiation. The scattering matrix is found for a planar wave interacting with a weakly anisotropic spherical particle in an arbitrary coordinate system, i. e. a system that is not associated either with the principal axes of the permittivity tensor or the direction of propagation of the radiation. An examination is made of cases of wave scattering by an aggregate of particles both with preferred and with random spatial orientation of the principal axes of the permittivity tensor. The author thanks V. A. Babenko and A. P. Prishivalko for useful advice and constructive criticism. References 5 Russian.
[69-6610]

ANGULAR AND ENERGY DISTRIBUTION OF REFLECTED PARTICLES WHEN AN ION BEAM IS INCIDENT AT SMALL ANGLES TO THE SURFACE OF A SUBSTANCE

Moscow ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 79, No 2(8), Aug 80 pp 448-458 manuscript received 5 Mar 80

REMIZOVICH, V. S., RYAZANOV, M. I. and TILININ, I. S., Moscow Engineering Physics Institute

[Abstract] The authors consider the part played by particle backscattering in the radiation resistance properties of solids. Up until now it has been difficult to analyze experimental results in depth because of the lack of a simple analytical solution of the particle reflection problem. In this paper, the complete distribution of reflected particles is found with respect to angles and energies, and the theoretically found distribution is compared with experimental data. It is assumed that a wide monoenergetic beam of ions with given initial

energy is incident at a glancing angle on the surface of a flat homogeneous target. It is assumed in addition that the effective angles of scattering of particles by atoms of the target are small compared with the characteristic angles of the problem. The angular and energy distribution found in this research is applicable to a broad range of ion velocities from atomic to relativistic. The proposed theory of particle reflection with glancing incidence agrees well with experimental data. Figures 3, references 26: 16 Russian, 10 Western.
[95-6610]

UDC 539.186

EXCITATION OF PLASMA WAVES IN A MEDIUM WITH NONLINEAR OPTICAL ACTIVITY

Minsk DOKLADY AKADEMII NAUK BSSR in Russian Vol 24, No 11, Nov 80 pp 983-985
manuscript received 8 Apr 80

BOKUT', B. V., associate member of the BSSR Academy of Sciences, GVOZDEV, V. V. and SERDYUKOV, A. N., Gomel' State University

[Abstract] The electromagnetic properties of isotropic media with consideration of nonlinear optical activity can be described by a system of material equations that yield solutions in the form of planar monochromatic circularly polarized waves in the linear approximation with Maxwell's equations for a free field in the case of non-zero permittivity. It is shown in this paper that the nonlinear polarization induced in the medium by the field of these waves may give rise to plasma waves. The optimum condition for excitation of plasma waves corresponds to linear polarization of the fundamental plane monochromatic wave. Analysis of the polarization of the medium due to the nonlinear Faraday effect in a longitudinal magnetic field shows that this may also be a source of plasma waves in the case of zero permittivity. References 6 Russian.
[80-6610]

UDC 517.934

CONTROLLABILITY OF LINEAR SYSTEMS IN THE CLASS OF UNBOUNDED IMPULSE CONTROLS

Minsk IZVESTIYA AKADEMII NAUK BSSR: SERIYA FIZIKO-MATEMATICHESKIKH NAUK
in Russian No 5, Sep-Oct 80 pp 34-41 manuscript received 22 Aug 79

MORDUKHOVICH, B. Sh. and SAVIKOVSKIY, V. I., Belorussian Scientific Research Institute of Land Reclamation and Water Management

[Abstract] The authors consider problems of controllability of unsteady linear systems on a fixed time segment with convex noncompact constraints on control. It is shown that the class of summable controls does not guarantee closure of the set of attainability, and cannot be used for investigating exact controllability

in the general case. The permissible controls are extended to the class of impulse actions, where closure is demonstrated for the set of attainability under general assumptions. Explicit sufficient conditions of controllability are presented in the case where the control region is assigned by a convex polyhedral cone. The principle of duality can be used to derive sufficient conditions of controllability of the given system for other cases of assignment of the control region. References 8: 6 Russian, 2 Western.
[82-6610]

THERMODYNAMICS

UDC 536.24

HEAT TRANSFER ACCOMPANYING VAPORIZATION IN A LIQUID FILM RUNNING OVER A VERTICAL PROFILED SURFACE

Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 39, No 5, Nov 80 pp 833-837
manuscript received 8 Oct 79

RIFERT, V. G., Kiev Polytechnical Institute

[Abstract] An investigation is made of heat exchange as a liquid film evaporates with flow over fluted or corrugated surfaces such as those used in vertical tubes in the evaporators of desalinating facilities. A theoretical analysis is made of the influence that the wall has on the intensity of heat transfer, and an expression is given that accounts for this effect in the average heat flux density. Experimental data are presented on the average heat transfer to an evaporating film of liquid running over fluted tubes, and a generalizing expression is proposed for these data. Figures 4, references 8: 5 Russian, 3 Western.
[93-6610]

UDC 542.51

IGNITION OF INITIATING EXPLOSIVES BY PULSED LASER EMISSION

Minsk DOKLADY AKADEMII NAUK SSSR in Russian Vol 256, No 5, 1981 pp 1152-1155
manuscript received 10 Jul 80

KARABANOV, Yu. F. and BOBOLEV, V. K., Institute of Chemical Physics, USSR Academy of Sciences, Moscow

[Abstract] The use of pulsed laser radiation for initiating fast reactions in explosives requires determination of the mechanism of the initiating process. This article is a report on experimental investigation of the ignition of typical initiating explosives: lead styphnate, fulminate of mercury, tetrazene and heavy-metal azides. Initiation was by laser pulses with wavelength of 0.69 and 1.06 μm at durations of $5\cdot10^{-8}$ s (short pulse) and 10^{-3} s (long pulse). By an arrangement of beam splitters and lenses, the laser emission was simultaneously to the specimens of pressed explosive and to instrumentation for measuring the parameters

of the laser emission and the explosion: the critical energy density of laser emission, the explosion delay time and the dependence of these parameters on the compression of the explosive specimen up to 20 kbar. The critical energy density was found to be anomalously low (0.015-0.4 J/cm^2 for a short pulse and 2.1-4.0 J/cm^2 for a long pulse depending on the type of explosive). The critical energy density was independent of wavelength, decreased with increasing compression of the explosive, and increased with pulse duration. The results are explained by a mechanism of localized initiation in microfoci produced by radiation absorption in microinhomogeneities such as chemical impurities, particles of carbon or metal and other uncontrolled optical inhomogeneities. Figures 2, references 6 Russian.
[91-6610]

UDC 536.24:532.517.4

INFLUENCE OF INLET AND OUTLET CONDITIONS ON HEAT EXCHANGE IN AN ANNULAR CHANNEL FOR LAMINAR FLOW

Kishinev IZVESTIYA AKADEMII NAUK MOLDAVSKOY SSR: SERIYA FIZIKO-TEKHNICHESKIKH I MATEMATICHESKIKH NAUK in Russian No 2, May-Aug 80 pp 88-89 manuscript received 9 Apr 79

MOSYAK, A. A., MUSTYATSA, V. T., POPOVICH, V. P. and TETLYA, Yu. Ye.

[Abstract] To solve the problem of heat removal in the cooling jacket of electric motors that drive hermetically sealed pumps, an analysis must be made of the case of heat exchange with radial inlet and outlet of the coolant in an annulus of comparatively short length. In this paper experiments are done to study the factors that influence the intensity of heat exchange under these conditions. The annulus was formed by coaxial cylinders, the inner cylinder being made of copper heated from within by a nichrome heater so that the heat flux density at the surface was constant. Outer cylinders were made of steel with different inside diameters so that the gap between the cylinders could be varied over a range of 2-8 mm. The measurements were made at Reynolds numbers of 60-210, and Prandtl numbers of 6.7-9.2. The results are given as curves $Nu/(\delta L)^{0.75} = f(1/Pe)$, where δ is the gap between cylinders, and the characteristic linear dimension is the equivalent diameter. It was found that as the ratio of gap to channel length increases, the experimentally determined Nusselt numbers are higher than theoretical values calculated by conventional relations for heat exchange in annular channels for axial flow. Figures 2, references 4 Russian.
[72-6610]

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